From the onset: Impact of Nutrition and Lifestyle during the Preconception period in Urban South African Young Adults

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Declaration

I, Gudani Goodman Mukoma, declare that this thesis is my own original, unaided work. It is being submitted for the degree of Doctor of Philosophy at the University of the Witwatersrand, Johannesburg, South Africa. It has not been submitted before for any degree or examination at any other university or institution.

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GG Mukoma

Date: 31/03/2023

Dedication

Dedicated to all South African youth facing multiple challenges to adopting healthy behaviours, stay resilient; the future depends on you.

Acknowledgements

I would like to express my profound gratitude to Professor Shane Norris, who served as my PhD supervisor, for providing me with the priceless opportunity to complete my PhD while working under his direction. I am grateful to him for all his expertise, knowledge, direction, and help throughout the process of earning my PhD. In addition to the contribution made by my PhD supervisor, I will be eternally grateful for the support I received from a variety of professionals who contributed to my PhD, from the conception of the study through the data analysis and interpretation to the drafting and revision of the various manuscripts that culminated in this thesis. These individuals include Lisa Micklesfield, Stephanie Wrottesley, Juliana Kagura, Tolu Oni, Edna Bosire, Sonja Klingberg, and Tinashe Chikowore. This study would not have been possible without the consistent support and assistance of an excellent research team: Molebogeng Mothlathledi, Phumzile Mathe, Melikhaya Soboyisi, Karabo Moloi, Meikie Hlalele, and Tshifhiwa Ratshikombo. In addition to the research team, I would like to express my utmost gratitude to the respondents who took part in our interviews and focus group discussions, as well as the families in Soweto who opened their doors to us and invited us into their homes. Without the support of the SAMRC/Wits Developmental Pathways for Health Research Unit and the DSI-NRF Centre of Excellence in Human Development, this series of studies as well as my PhD in its entirety would not have been possible. My wife Abigail, my children (Dziphathutshedzo, Andisa, Unarine and Vhuthuhawe), my parents, my close friend Deekay as well as the rest of my family, friends and colleagues, have provided me with unflinching support and unwavering faith in my capabilities. For this, I am eternally grateful. My sincerest thanks and gratitude

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Thesis Material and Contributions

The new data collection design in this thesis was a collaborative effort between my supervisor and myself. In addition to developing the questionnaires, standard operating procedures, and data collection procedures, I also contributed to the development of the study protocol. I led the focus group discussions on the impact of COVID-19 on young people, young people's perceived barriers and solutions to healthy eating and physical activity, and collected data on adolescent, young adult, and middle-aged adult anthropometrics, household socioeconomic status, physical activity and sedentary behaviour, and food frequency questionnaires. As part of my role, I was also responsible for project management, quality control, and data management for the surveys, as well as statistical analysis of all results.

Funding and Awards

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Publications and Presentations

While completing this Ph.D. thesis, a portion of its findings were reported and published in a variety of international, peer-reviewed scientific journals. This investigation's findings were also presented as poster presentations at various academic and scientific conferences.

Peer Reviewed Publications:

Paper 1 (Chapter 3)

Gudani Mukoma, Stephanie V Wrottesley, Juliana Kagura, Tolu Oni, Lisa Micklesfield & Shane A Norris (2022): The relationships between socioeconomic status, dietary knowledge and patterns, and physical activity with adiposity in urban South African women. South African

Journal of Clinical Nutrition (Published online: 06 June 2022). DOI: 10.1080/16070658.2022.2076374 (Appendix R)

Paper 2 (Chapter 4)

Mukoma, Gudani Goodman, Edna N. Bosire, Sonja Klingberg, and Shane A. Norris. "Healthy eating and physical activity: analysing Soweto's young adults' perspectives with an intersectionality lens", PLOS Global Public Health (Revisions submitted: 31 March 2023).

Paper 3 (Chapter 5)

Gudani Mukoma, Edna N Bosire, Polly Hardy-Johnson, Mary Barker, Shane A Norris. *'We were not allowed to gather even for Christmas.'* Impact of COVID-19 on South African Young People: Exploring Messaging and Support, Global Public Health (Revisions submitted: 03 March 2023).

Paper 4 (Chapter 6)

Mukoma, Gudani, Shane A. Norris, and Tinashe Chikowore. "Nutrient Patterns and Body Mass Index: A Comparative Longitudinal Analysis in Urban Black South African Adolescents and Adults." *Nutrients, 15(5), 1075; https://doi.org/10.3390/nu15051075* (Published: 21 February 2023) (Appendix P)

Conference Proceedings:

Witwatersrand 13th Cross Faculty Postgraduate Symposium, Parktown Johannesburg, South Africa (2022). Poster Presentation: Examining the relationships between socio-economic status, dietary knowledge and patterns and physical activity with adiposity in urban South African women.

Preface

My reason to pursue this doctoral degree began with being fascinated by health promotion, and more specifically, how diet and exercise are useful tools to improve people's health immensely while incurring almost no to low expense. Since the majority of South Africans (SA) are economically disadvantaged, experience high levels of food insecurity and a double burden of under and over nutrition, I was curious as to how nutrition and physical activity can be bolstered to benefit health with little to no outlay of funds. Having a healthy population is crucial to economic growth, personal wealth accumulation, and one's overall quality of life. As a result, this has a multiplicative effect on well-being, wealth, and even economic development. Research shows that a healthy lifestyle consists of eating a balanced diet, exercising regularly, keeping oneself clean, having access to safe housing, and getting enough sleep. Also, physical activities that help with both weight and stress management are important for everyone to participate in. It goes without saying that many factors are at play; however, the fact that individuals are at a higher risk for non-communicable diseases (NCDs) when they fail to meet all of the above requirements significantly ups the ante.

Scientific evidence shows that reducing the risk of developing NCDs can be achieved through increasing one's level of physical activity and improving one's diet, as these are two of the four most common causes of NCDs (the other two being tobacco use and alcohol use). Despite the plethora of information available, the health of adolescents and young adults is only now attracting serious attention. Young people's health needs were traditionally considered less important than those of other groups such as the elderly, mothers and babies. Young people were considered healthy, so while there were clearly special groups within the age cohort, the adolescent population did not need to be a health service delivery priority. However, rising teenage pregnancy rates, gender-based violence, HIV, food insecurity, overweight and obesity, alcohol and drug abuse, and social issues such as youth unemployment, anxiety, and depression have changed this perception, especially in the context of SA. The future generations of SAs are also at risk because of these problems that plague today's youth. Due to my prior research on exercise and pregnancy for my master’s degree, I now know that it may be too late to intervene to improve health during pregnancy and that few women in South

Africa plan their pregnancies. Adolescence is a pivotal time to improve health-related behaviours like nutrition and physical activity before conception, and the benefits can extend all the way to their offspring. For these reasons, I chose to do this research to fill in the gaps in what we know about adolescent nutrition and lifestyle behaviours, factors affecting them, and their relation to adiposity in order to identify levers for intervening to improve preconception health.

The outline of this thesis is illustrated below:

Part 1: Introduction

Introduction Chapters 1 and 2 include the background of the study comprising the problem statement and conceptual framework, literature review and methods for this series of studies.

Part 2: Empirical Chapters

Chapters 3-6 contain details of the studies undertaken; utilizing data collected over the course of this PhD.

1: Examining the relationships between socio-economic status, dietary knowledge and patterns and physical activity with adiposity in urban South African women.

2: *"We were not allowed to gather even for Christmas."* Impact of COVID-19 on South African Young People: Exploring Messaging and Support.

3: Healthy eating and physical activity: analysing Soweto's young adults' perspectives with an intersectionality lens.

4: Nutrient patterns and body mass index: A comparative longitudinal analysis in urban Black South African adolescents and adults.

Part 3: Integrated Discussion and Conclusion

Chapter 7 comprises an integrated discussion of the thesis, synthesizing the main research findings; a re-evaluation of the conceptual frameworks used in this thesis and concludes with an evaluation of the study strengths and limitations, the relevance, and implications of these findings, as well as future research considerations.

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Nomenclature

PA: Physical Activity

NCD: Non-communicable Disease

BMI: Body Mass Index

SES: Socio-economic Status

LMIC: Low- and Middle-Income Country

HIV: Human Immune Virus

AIDS: Acquired Immune Deficiency Syndrome

SA: South Africa

SSA: sub-Saharan Africa

GDP: Gross Domestic Product

DOHaD: Developmental Origins of Health and Disease

DPHRU: Developmental Pathways For Health Research Unit

T2DM: Type 2 Diabetes Mellitus

CVD: Cardiovascular Disease

TV: Television

MVPA: Moderate-to-Vigorous Physical Activity

WHO: World Health Organisation

NDOH: National Department of Health

GDAR: Global Diet and Activity Research

HREC: Human Research Ethics Committee

DVD: Digital Optical Disc

QFFQ: Quantitative Food Frequency Questionnaire

SAMRC: South African Medical Research Council

GPAQ: The Global Physical Activity Questionnaire

PCA: Principal Component Analysis

PC: Principal Component

VIF: Variance Inflation Factor

SEM: Structural Equation Modelling

RMSEA: Root Mean Squared Error of Approximation

TLI: Tucker-Lewis index

CD: Coefficient of determination

SRMR: Standardized Root Mean Squared Residual

NKQ: Nutritional Knowledge

CHBAH: Chris Hani Baragwanath Academic Hospital

FGD: Focus Group Discussion

NICD: National Institute for Communicable Diseases

GM: Gudani Mukoma

ENB: Edna Bosire

DNA: Deoxyribonucleic Acid

SPSS: Statistical Package for Social Scientists

GEE: Generalized estimating equations

EI/EER: Energy Intake/Estimated Energy Requirements

EER: Estimated Energy Requirements

IOM: Institute of Medicine

DLW: Doubly Labelled Water

CIR: Carbon Isotope Ratio

Abstract

Background

In South Africa, 22% of adolescents are overweight or obese, the onset of tobacco smoking is shown to peak between the ages of 15 and 22, 1 in 3 adolescents watch more than 3 hours of television per day, and nearly half of all adults are insufficiently active. Physical inactivity, poor diet, risky alcohol use, illicit drug use are among the behavioural risk factors associated with obesity and mental health problems, all of which have morbidity and mortality implications for adult health. Risks in later life include premature death, long-term disability, childbirth complications, gestational diabetes, diabetes and cardiovascular diseases. However, there is data paucity showing the personal, social, and environmental factors that are determinants of health, especially diet, physical activity (PA), obesity, and associated NCDs in South African adolescents and young adults.

Aim

To investigate the individual, household, and environmental factors that influence adolescents' dietary and physical activity habits and to identify ways in which these factors can be leveraged for interventions to better ensure the health of future generations, especially during the crucial preconception years.

Methods

This thesis was purposely designed to use a sequential mixed-methods approach that integrates quantitative (Chapter 3 paper 1: cross-sectional and Chapter 6 paper 4: longitudinal) and qualitative (Chapter 4 paper 2: longitudinal and Chapter 5 paper 3: cross-sectional) analyses in order to meet the four specific objectives of my research. The methods selected for this series of investigations were primarily influenced by the substantive research questions that arose, as opposed to methodological and epistemological concerns alone. I utilized three pre-existing data sources, including the "Birth-to-Twenty Cohort," the "Determinants of Type 2 Diabetes Mellitus (T2D)" study, and the "Soweto household enumeration survey." I have gathered new prospective data that is quantitatively and qualitatively longitudinal and cross-sectional.

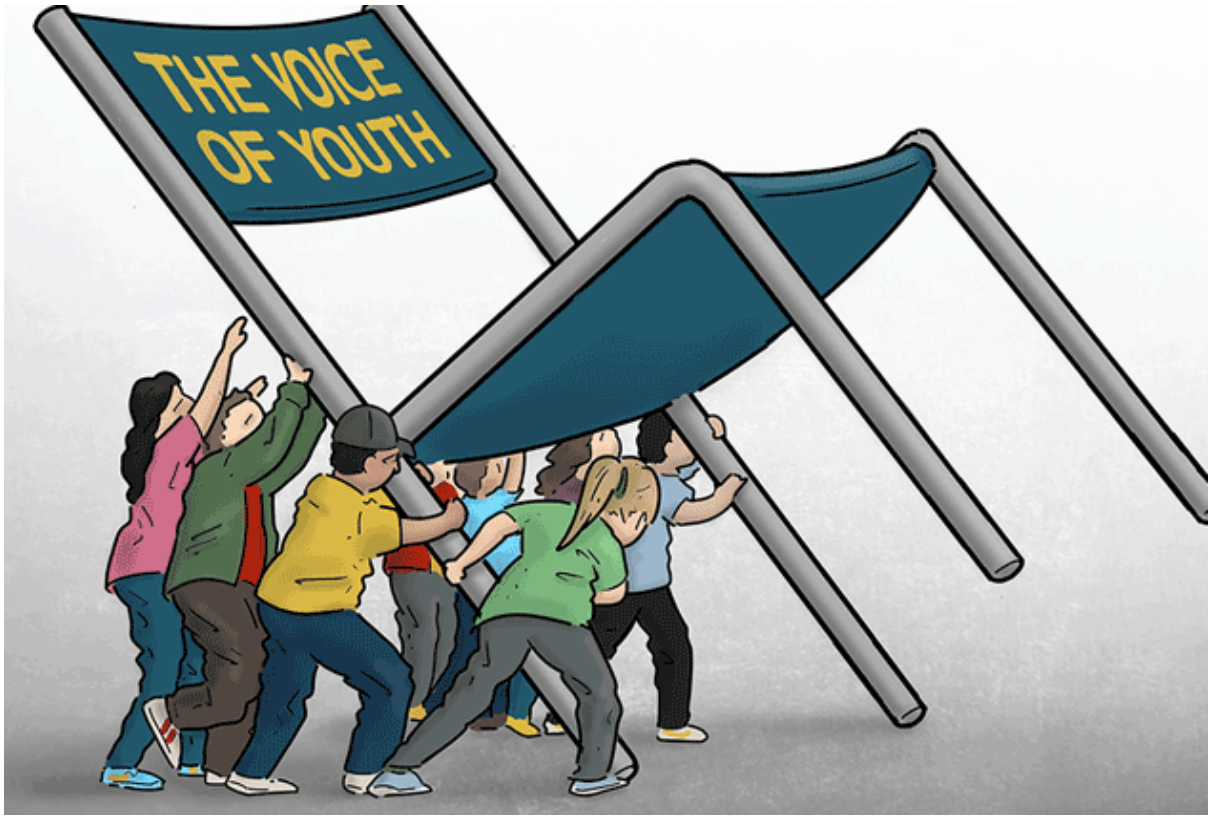
Results

The findings of this thesis in the context of Soweto show that the relationship between dietary patterns and nutritional status (BMI) is independent of socioeconomic status (SES). Adolescents and young adults face a variety of intersecting barriers resulting from personal preferences and their living conditions, which influence their dietary and physical activity habits while occurring at the time; this is important to consider when designing interventions to promote healthy behaviour change. Unexpected stressors, such as the outbreak of the COVID-19 pandemic, contributed to exacerbating adolescents' and young adults' poor health conditions, and as a result, the prevalence of poor nutrition intake, a lack of physical activity, and mental health issues increased. Although the nutrient patterns of adolescents and adults were comparable over time, their associations with BMI were not. The associations with BMI of the "plant-driven nutrient pattern," "fat-driven nutrient pattern," and "animal-driven nutrient pattern" revealed sex differences.

Conclusion

Adolescent diet and lifestyle continue to be important research areas in the intent to enhance preconception health and reducing maternal and infant mortality.

Part 1: Introduction



*We cannot always build the future for our youth, but we can build our youth for the future – **Franklin D. Roosevelt***

Chapter 1: Background and Literature Review

1.1 Problem statement

Non-communicable diseases (NCDs) are four times more likely to cause early death in low- and middle-income countries (LMIC) than in high-income countries (1, 2). By 2030, NCDs are expected to make up almost half of the global disease burden in LMIC (3, 4). Studies on the burden of disease show that young people of ages 10–24 years are increasingly at a high risk of getting sick and dying prematurely (5). The world now has more young people than ever before; over 42% of the world's population are younger than 25 years old (6). For a long time, there has been an assumption – sustained by critical gaps in data - that adolescents are healthy (7). Every day, about 3000 teenagers die around the world, and more than 1.1 million 10–19-year-olds died in 2016 mostly from events that could have been prevented, like complications during pregnancy or childbirth, or HIV/AIDS (6). Up to 70% of premature adult deaths reflect behaviours started or reinforced during adolescence (8-10). Even though the death rates of babies and mothers have gone down over the past few decades the number of people with chronic NCDs, and obesity has gone up (11, 12).

This is also true in sub-Saharan Africa (SSA), where obesity and other NCDs are increasing rapidly, particularly in South Africa (SA) (13). According to a 2015 estimate, the total cost of diabetes in sub-Saharan Africa was US$19.45 billion, equivalent to 1.2% of the region's gross domestic product (GDP) (14). The region's health care infrastructure was inadequate to deal with diabetes and its complications (14). These rising costs of treating NCDs are of great concern because SSA countries are dealing with higher rates of NCDs at earlier stages of economic development when they have fewer resources and less time to respond effectively (15). In addition, more than a third of the total population of sub-Saharan Africa is between 10 and 24 years old. This means that the burden will continue to increase if effective interventions are not available (16).

In SA, more than half of deaths (50.9%) have been attributed to NCDs (17). Economic, social, political, and environmental determinants of health, such as poverty and the uneven distribution of wealth, poor education and lack of knowledge, rapid urbanization and urban

migration into informal settlements, as well as, environmental risks are contributing to the rapid rising incidence and prevalence of NCDs (18, 19). Because of this, the latest South African Demographic Health Survey found that 35% of children aged 6-23 months consumed sugary foods and 18% consumed sugary foods on a daily basis (19). Almost 70% of women and more than 30% men (15+ years) in SA are overweight or obese, of which 46% and 44% (women vs men) of them have high blood pressure (19, 20). It is unsurprising that more women have a higher prevalence of obesity than men as they also have significant amounts of physical inactivity (70.8 vs. 40.7%, respectively) (21, 22). Conversely, 28% of men and 5% of women who are 15 or older regularly consume alcohol, while 37% of men and 8% of women do the same with tobacco (19). This evidence supports the notion that behavioural risk factors such as physical inactivity, poor diet, risky alcohol use, illicit drug use, and unprotected sex, which are associated with obesity, sexual transmitted diseases, teenage pregnancy and mental health problems, which have morbidity, and mortality implications for adult health begin to emerge before and during adolescence (23, 24). Premature death, long-term disability, child birth complications, gestational diabetes, type 2 diabetes, ischemic heart disease, hypertension, and cerebrovascular disease are among the risks that one faces in later life (25). However, very limited evidence focusing on the personal, social, economic and environmental determinants diet, physical activity (PA), obesity and associated NCDs in SA adolescents and young adults exists (26).

It is well known that a mother's diet and lifestyle have a substantial impact on her child's growth and development (27-30). However, data shows that the benefits of investing in maternal and child health programs are not necessarily sustained in adolescence; the drop in child deaths was not matched by a drop in adolescent deaths (6). Also, most research and intervention strategies have focused on the mother's nutritional status, diet, and PA during pregnancy, even though the mother's risk profile is already known and there isn't much that can be done to change the outcomes for both mother and child (27, 28, 31). Additionally, with the rising rate of teenage pregnancy in SA, it goes without saying that most women do not plan their pregnancies, especially when they have low education and income levels (32, 33).

During 2021, teenage pregnancy (15-19 years) shot up to 39% in Gauteng province alone since the start of the COVID-19 pandemic (34). Miscarriage, gestational diabetes, operative delivery, pre-eclampsia, infant perinatal mortality, and macrosomia are all more likely when the mother is obese prior to conception (35). Adolescent growth and social development are known to shape the early development of offspring from conception to the post-partum period in males and females through distinct processes (36). The COVID-19 pandemic has demonstrated that indeed adolescents face multiple multilevel barriers to adopting health-related behaviour (37, 38).

However, researchers still have not paid enough attention to addressing them all at the same time, such as how a father's nutritional status, attitudes, and behaviours may affect his partner or offspring (31). Prevention efforts are important, particularly for young women and men at preconception, mainly because many of the health behaviours and risk factors that result in adverse birth outcomes are set up before pregnancy and have the most impact on future generations (39). Therefore, to improve health and well-being across generations, a focus on both male and female adolescents' nutritional status and develop interventions to encourage healthy attitudes and behaviours about diet, PA, drug use, and stress during this period is crucial (39-41).

1.2 Life-course epidemiology, preconception health and conceptual frameworks

To effectively combat NCDs, several major international organizations and research fields have emphasized the significance of taking a life-course approach (42-44). This is due to the fact that a person's health, illness, and disease patterns are influenced by a trifecta of their genetic makeup, epigenetics, and the external environment at various points in their life (45). The Developmental Origins of Health and Disease (DOHaD) theory, which postulates that responses to different stimuli during early development are likely to program the risk of metabolic and other NCD disorders (46-48), is supported by substantial evidence from the scientific literature.

The life-course approach is a concept that recognizes the opportunity to prevent and control diseases at key stages of life, beginning with preconception and continuing through pregnancy, infancy, childhood, and adolescence, and then into adulthood (48-50).

Longitudinal or intergenerational influences on the onset of chronic diseases can be traced back to a wide range of biological, behavioural, and psychosocial trajectories (50). It places an emphasis on a historical and social perspective, one that looks back over the lifetime of an individual, a group of people, or even several generations to make sense of current health and disease trends (50, 51). In addition, it acknowledges that the larger social, economic, and cultural context influences both the past and the present (51). This means that environmental exposures in early childhood, adolescence, and adulthood may alter or condition the later risk of chronic NCDs (43). Epidemiological studies conducted in a wide range of countries over a significant amount of time have corroborated the finding that exposures during early human development, particularly adolescence, affect the risk of NCDs later in life (23, 41, 52, 53). Because of the emergence of behavioural risk factors that have implications for adult health before and during adolescence, this makes adolescence a crucial window (Figure 1) in which behaviours that will promote and maintain health throughout the life course are established (6, 39, 41).

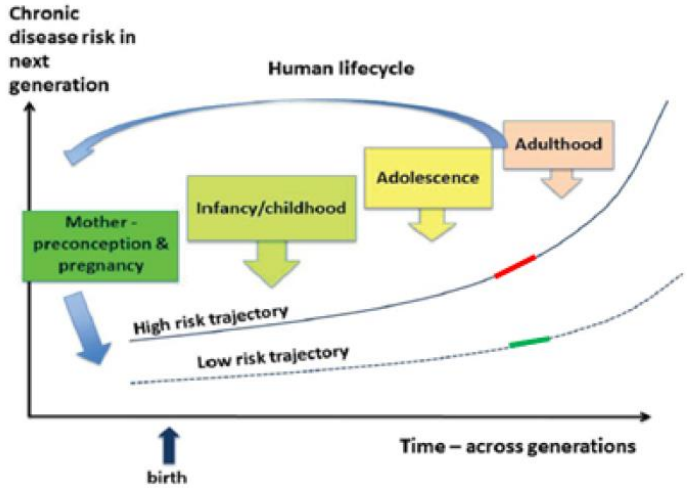


Figure 1: *DOHaD Life course model for the risk of chronic disease (51).*

This DOHaD model is showing how significant the adolescent/young adulthood period is for interventions to lower the risk of chronic disease in the current and future generations. Response time to a brief challenge is used to quantify trajectories' tangents, with high risk (red) and low risk (green) as indicated above (51).

In 2012, the Lancet Commission on Adolescent Health and Wellbeing series (23) developed a framework (Figure 2) that emphasizes the need to focus on adolescents and the crucial importance of a life-course perspective in the understanding of adolescent health and development. This framework applies a life-course perspective and emphasize that adolescent health is shaped by social determinants as well as risk and protective factors that influence the adoption of health-related behaviours and is the result of interactions between prenatal and early childhood development as well as the specific biological and social-role changes that accompany puberty (23, 49). Additionally, the beginning of these behaviours and states during adolescence have an effect not only on the disease burden that adults experience but also on the health and development of their children. This is because the behaviours and states are passed down from parent to child (23).

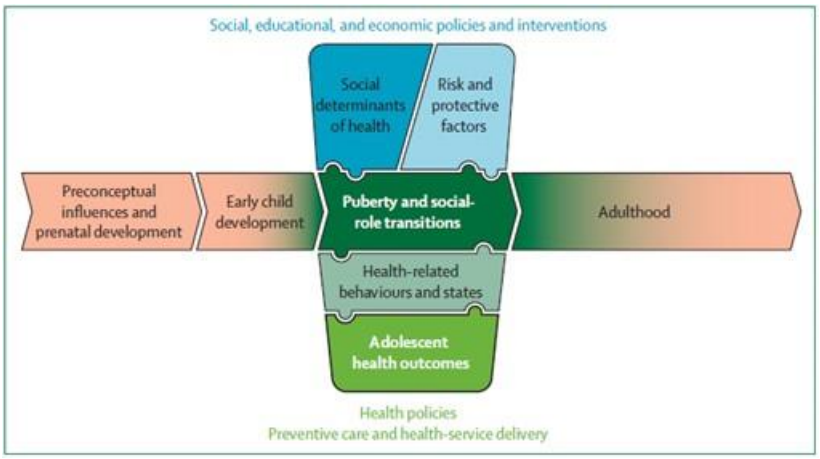


***Figure 2**: Conceptual framework of 2012 Lancet series (23).*

The 2012 Lancet series framework showing the importance of a life-course perspective in understanding adolescent health and development (23). The framework was then adapted in the 2016 Lancet Commission on Adolescent Health and Wellbeing (7) to define the health needs of adolescents and young adults at three levels: current health problems and causes of adolescent and young adult deaths; health risks for health problems in adolescence, adulthood, or the next generation; and important proximal social determinants of health during the adolescent and young adult years (Figure 3).

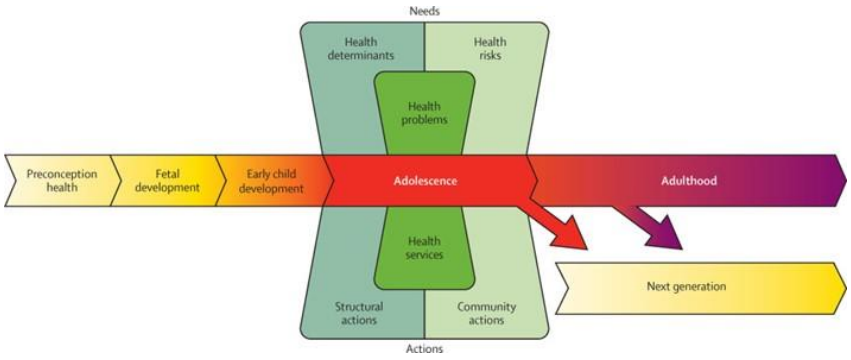


Figure 3: *The adapted 2016 Lancet series conceptual framework for defining adolescent's health needs and actions* (39*).*

This framework illustrates how targeting behaviour changes during adolescence can have a lasting effect on the trajectory of an individual's life-course, with potential benefits for both the individual's own health and the health of their offspring (7, 23). It provides an all-encompassing view of the several factors that determine adolescent health and their interactions. It is well known that as young adults and adolescents grow older, the influence of their peers, the media, school, and the workplace, all of which are proximal social determinants of health, all become significant factors in their health-related behaviours such as PA and eating healthy (7).

According to the 2016 Lancet series (39) research, adolescence is a transitional period in human development that is influenced by nutrition during childhood while also establishing nutritional pathways for later life and the next generation, as shown in (Figure 4) below (blue arrows). The immediate food environment of an adolescent (indicated by the grey arrow) has a significant impact on the development and maturation of their physiological systems, which in turn shapes their dietary intake and norms, levels of PA, and body image preferences (multi-coloured ribbon). A variety of ecosystems, including cultural, economic, commercial, and environmental ones, shapes the food environment. This influence pervades the family and community environments in which adolescents grow. Adolescents, on the other hand, have an increasing ability (salmon arrow) to exert influence over the ecosystems that determine the nature of their food environment (46).

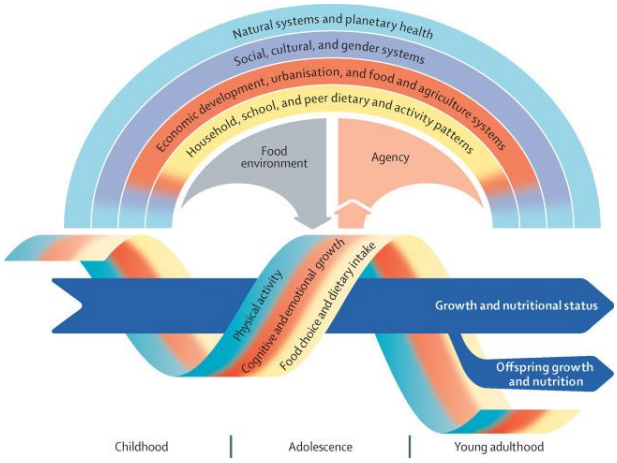


***Figure 4**: The 2016 Lancet Commission on Adolescent Health and Wellbeing conceptual framework for adolescent growth and nutrition .*

In relation to this thesis, the Lancet series frameworks (Figure 3 and 4) have a good deal of bearing on the overarching purpose of the present investigation, which is to establish how different health determinants (individual, household, and neighbourhood) influence adolescent health-related behaviours (i.e., physical activity, dietary patterns, and knowledge) that leads to a specific health outcome (nutritional status) in order to identify potential intervention levers to improve preconception health during the adolescent period (Figure 5).

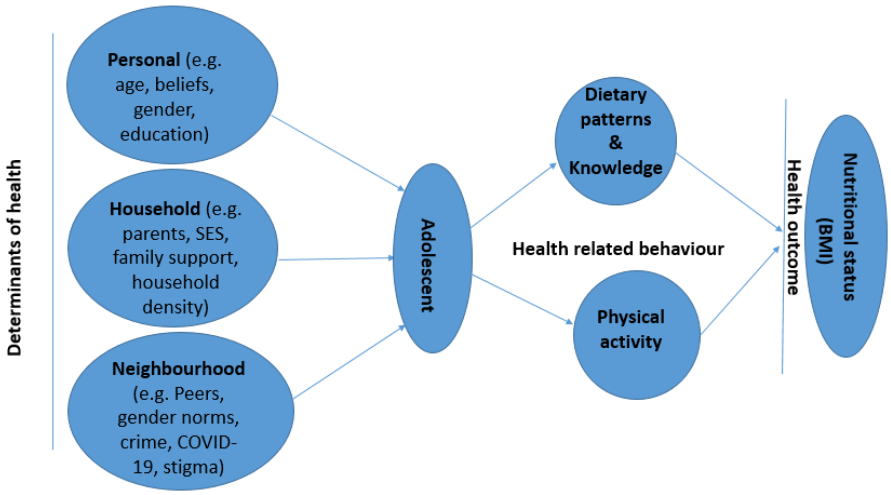


***Figure 5**: This thesis's conceptual framework for the health determinants of adolescent health, behaviours, and health outcome of focus.*

1.3 Literature review

1.3.1 The nutrition transition

As low- and middle-income countries (LMICs) become more urban, they experience profound demographic and lifestyle shifts, including the adoption of Western diets and decreased levels of PA (54). Changes in dietary patterns toward more energy-dense diets high in saturated fat, added sugar, and salt and processed or convenience foods low in fibre and essential micronutrients have been linked to the emergence of the burdens of type 2 diabetes mellitus (T2DM) and cardiovascular disease (CVD) (55, 56). However, the rate of urbanization and the severity of the metabolic and health consequences that have resulted from this vary greatly between contexts (57-60). In countries like SA, where the change has been especially dramatic, the implications for adolescent and young adult health are particularly far-reaching (40, 60-64). Until recently, teenagers and young adults were always considered healthy (6). However, by 2012, nearly 38% of females and slightly more than 13% of males aged 15 and over were obese (65). According to the most recent SA national survey, 68% of adult women, 28% of adult men, and 40% of young women and 11% of young men (15-24 years) are overweight or obese (66). Being overweight or obese is one of the important risk factors for developing NCDs related to diet and lifestyle behaviours, such as diabetes and CVD (18). Furthermore, NCDs such as obesity, diabetes, and cardiovascular disease have been identified as the world's leading causes of death (67). On top of that, we still find that 27% of children under 5 in SA are short for their age, 3% are obese, 6% are underweight, and 13% are overweight (28, 66, 68). SA is dealing with a double burden of malnutrition, as obesity rates are rising at an alarming rate, and undernutrition is still persistent.

1.3.2 Adolescent phase

The Lancet series on adolescent health recognizes adolescence as a period of life that encompasses the age range of about 10–24 years and a process of various changes that occur rapidly and intensively (69). It is a critical phase marked by dynamic brain development, in which the way a person interacts with his or her social environment shapes the competences that the person will have as an adult (70). It is during this phase that physical, psychological, and social development, as well as increasing levels of socialization with peers and independence outside of the family that are the foundation for later life health and wellbeing

occurs (41, 71). In addition, the adolescent period is characterized by significant changes in body composition, insulin sensitivity, physical activity, sedentary and dietary behaviours, and psychological issues that place adolescents at an increased risk of becoming overweight and maintaining obesity in adulthood (41, 52, 53). Because of these factors, adolescence is often referred to as a sensitive phase. This is because it is during this time that the quality of an individual's physical, nutritional, and social environments can influence the health and development trajectory that they will follow into later life (53, 69).

1.3.3 Modifiable drivers of adolescent health

Much of the global disease burden can be traced back to avoidable causes like smoking, drinking excessively, being overweight or obese, sedentary behaviours and poor dietary habits (4, 72). These can increase the risk of chronic diseases like heart disease, diabetes, and cancer by causing conditions like high blood pressure and elevated blood glucose and cholesterol levels (11, 12). As such, LMICs are now facing a double burden of chronic NCDs and infectious diseases. This is a result of declining infectious disease rates, shifting diets and levels of PA, and an ageing population (73).

1.3.3.1 Substance abuse

Adolescents are the most likely to try substances like tobacco, alcohol, and other drugs, with subsequent use and dependence often beginning in the early adult years (74-76). Commonly, adolescent boys and young men experience a sharp increase in the rates of daily smoking and alcohol-use disorders compared to girls and young women (77). Nearly 80% of the world's more than a billion smokers live in LMIC countries, where the cost of tobacco use is highest. Despite this, economic deterioration and an insufficient supply of health services in this countries persist, and the risk of NCDs is rising (78). While it is known that the consumption of more than three alcoholic drinks per day during pregnancy is a predictor of adverse birth outcomes (79). Persistent maternal use of tobacco, alcohol, cannabis, and other illicit drugs during pregnancy is associated with negative outcomes such as poor foetal growth, low birth weight, stillbirth, sudden unexpected death in infancy, and a wide range of birth defects, along with later childhood behavioural problems, obesity, and impaired lung function (75, 80, 81). In addition, weekly intake of alcohol prior to the age of 17 is a risk factor for later alcohol

dependence and abuse in adulthood (75, 79). Moreover, chronic liver disease, cardiovascular disease, unintentional injuries, neuropsychiatric disorders, certain cancers, and societal problems like alcohol-related violence and domestic abuse, which are common in adulthood, are all linked to excessive alcohol consumption that emerges during adolescence (82). Considering that, about 40% of pregnancies are unplanned, that detection usually occurs between 6 and 8 weeks into pregnancy, periconceptional exposure is likely to be very high in countries where adolescent substance use is common (83-86).

1.3.3.2 Poor diet

Eating habits of adolescents are formed as a result of a complicated process that involves both internal and external elements, such as adolescent's food choices and availability, their assessment of their body weight, and the impacts of both parents and peers (87, 88). The medical community is aware of the fact that unhealthy eating habits can lead to nutritional issues, which in turn can hinder the progression of adolescent growth and development (89). In addition, eating patterns that are established throughout adolescence remain into adulthood; as a result, unhealthy dietary patterns among young people have significant implications for their health and well-being as adults (90). Individuals who do not consume enough fruits and vegetables put themselves at an increased risk for developing chronic diseases such as cancer, diabetes, hypertension, and cardiovascular disease (53, 91), which are among the top 10 leading causes of mortality around the world. An analysis of adolescents' food intakes indicates that the nutritional and health status of adolescents may be compromised (92). According to research findings, the overall amount of fat that adolescents consume has gone up, while at the same time their consumption of fresh fruit, vegetables other than potatoes, and milk has gone down, and their consumption of fibre is also insufficient (92-94). This dietary pattern, together with the rising prevalence of overweight adolescents (94), raises the risk for diabetes, hypertension, and cardiovascular disease in adulthood (3). Adolescence is a time of increasing autonomy, which includes an expansion of the range of options available for choosing what to eat and when to eat it (95). The quantity of free time that an adolescent has is one of the most critical aspects that plays a role in determining the kinds of foods that an adolescent chooses to eat. Adolescents spend more time away from home because of social, school, and community activities and jobs (96,

97). Also, because of the physical changes that come with puberty, there is a rise in concern about one's body in terms of its size, shape, and appearance (70). Peers and the media are two examples of external forces that have a substantial impact on adolescents' perceptions of their own bodies (23, 39). Discontentment among adolescents with their weight is associated with an increased likelihood of insufficient eating of dairy products, fruits, and vegetables (98).

1.3.3.3 Physical activity and sedentary behaviours

Several studies have reported an increase in the prevalence of overweight and obesity as a direct result of the majority of adolescents engaging in below-optimal levels of PA and spending the majority of their time in sedentary pursuits, such as watching television (TV) (62, 99). The 2012 Lancet Physical Activity Series reported that 80% of 13–15 year old's do not meet the minimum daily requirement of 60 minutes of moderate-to-vigorous physical activity (MVPA) per day, and emphasized the need for more physical activity surveillance data to come out of Africa (100). Although much is known about the positive effects that PA has on health outcomes at the present time, very little is known about the relationships between PA, sedentary behaviours, and a variety of risky behaviours that can be avoided by adolescents, such as alcohol-related accidents, paternal dietary habits and lifestyle, and sexually transmitted diseases (52, 63, 77, 101, 102). Adolescent lifestyles typically include multiple health-related risk behaviours, and we may be able to better understand these lifestyles and improve population-wide health promotion efforts if we characterize the associations between PA patterns and a wide range of these risk behaviours (62, 102, 103). PA and sedentary behaviours are best viewed as co-occurring behaviours rather than separate actions, even though they may operate through different behavioural mechanisms (103), have different determinants (104), and differentially track and influence disease risk independently (105, 106).

1.3.4 Adolescence within the life course

Trauma and social disadvantage in early childhood can lead to social isolation, low motivation to learn, poor academic performance, and the early onset of potentially harmful behaviours (107). A life-course perspective can help explain how prenatal and early life influence adolescents, and programs that improve maternal, infant, and child health will also benefit

adolescents. Health-related behaviours and outcomes in adolescence have a lasting impact on the health of these young people, but policymakers have not adequately addressed this. Foetal development, HIV, maternal malnutrition and micronutrient deficiency, obesity and gestational diabetes, and health-related behaviours such as alcohol, tobacco, and drug abuse are all affected by adolescent health. The adolescent health issue is of particular importance in SA, where there are many risk factors that can cause significant health issues in the future. While most studies have mainly focused on women, young adult men or boys' health-related actions may also affect future generations' health. As such, it is essential for policymakers to focus on adolescent health and develop strategies to ensure that young people have access to quality health services, education, and resources.

1.3.5 Obesity's implications on pregnancy and the next generation

The prevalence of obesity among women of reproductive age is high and continuing to rise (28, 63, 108). As of now, obesity (BMI ≥30 kg/m ^{2}) affects more than a third of women of childbearing age globally, and 10% of these women are morbidly obese (BMI ≥40 kg/m ^{2}) (108). It has been shown that obesity in this population is associated with unfavourable outcomes during pregnancy, and it has both immediate and long-term implications for the health of mothers and their children (108). Obesity is associated with foetal complications, including spontaneous abortion, foetal anomalies, foetal macrosomia, intrauterine growth restriction, and intrauterine foetal demise (109). Even when diabetes in the mother is considered, obesity is still linked to foetuses that are big for their gestational age. This is concerning because it increases the risk of obesity and metabolic syndrome in foetuses between the ages of 6 and 11 years old, which is when the risk is highest (109, 110). Babies born to mothers who experienced pregnancy-related complications due to diabetes are more likely to experience foetal macrosomia, increased adiposity, shoulder dystocia, birth trauma, and caesarean delivery. Additionally, they have a higher chance of developing type 2 diabetes later in life and becoming obese by the age of two (111).

1.3.6 The South African context

LMICs bear a disproportionate share of the global epidemic of NCD risk factors due to their high rates of adolescent obesity and inactivity (23). SA's urbanization, globalization, and

economic growth have all advanced rapidly since the country's democratic shift in 1994 (27, 66). Historically underserved black communities have now seen a dramatic shift in their food landscape as a result of legislative reforms on food production, composition, and availability, as well as economic accessibility and education (112, 113). As a result, obesogenic behaviours in adolescence, like irregular breakfast eating, fewer family dinners, increased snacking, and low levels of physical activity, now influence their dietary choices (114).

According to data from the Birth-To-Twenty plus Cohort and other studies conducted in the region, the vast majority of adolescents in Soweto, SA, do not meet the amount of physical activity recommended by the WHO (62, 63, 115). The WHO recommends that adolescents engage in at least 60 minutes of moderate-to-vigorous level physical activity (MVPA) on a daily basis, however only a small percentage of adolescent was able to satisfy this requirement (62, 63, 115). Findings from a different survey indicate that between 43% and 49% of SA adults (those aged 15 and older) engage in virtually no physical activity whatsoever during their waking hours (i.e., work at home, when traveling, or during their free time) (116). This was despite the evidence showing that an estimated 36,504 deaths in SA were attributable to obesity in the year 2000, or about 7% of the total number of deaths (117). Since then, the prevalence of overweight and obesity increased by 6% in boys and 7% in girls between 2002 and 2008, respectively (40). Currently, the prevalence of individuals who are overweight or obese in SA is the greatest in all of SSA (67, 118, 119).

According to the findings of a study carried out in a deprived rural area of SA, the combined prevalence of overweight and obesity among teenagers between the ages of 10 and 20 years ranged from 15 to 25% (90). Further, a 2016 survey by the South African National Department of Health (NDoH) found that roughly 27% of female and 9% of male adolescents in South Africa were overweight or obese by the time they were between the ages of 15 and 19 years old (66). It is undeniable that SA adolescents, and more specifically young women, are facing an ever-increasing burden of obesity as a direct result of urbanization-associated shifts in food intake and eating behaviours (40). Worryingly, this high rate of obesity prevalence persists into adulthood, particularly in women and becomes a greater health challenge in pregnancy (28, 63). As seen in a Soweto study, 66% of pregnant women who presented for their first antenatal

visit during the first trimester were either overweight or obese, and an analysis of their dietary patterns revealed that they consumed an abundance of energy dense, processed, high sugar/fat foods, which are associated with the risk for chronic NCDs such as diabetes and heart diseases (28).

Other research in the region supports that rapid urbanization exacerbates obesogenic behaviours by exposing young people to increasingly westernized diets that are high in saturated fat, added sugar, salt, processed foods, and edible oils, and to environments with low opportunities for physical activity (72, 120). Adolescents' dietary and PA choices have been shown to be influenced by a variety of personal, social, and environmental factors (40, 53, 62, 63, 96, 97, 121-123). While there are a few interventions and policies out there (124-128), none of them specifically address the adolescent population and do not consider the intersectionality of the multiple barriers young people face simultaneously in an attempt of leading healthy lifestyles (129). More importantly, because some adolescents may one day become parents themselves, improving their nutritional status is essential for the future health and well-being of the next generation (28, 53, 63). However, longitudinal data on modifiable risk factors such as dietary patterns spanning across adolescence remain inadequately unexplored. This is especially the case when considering the fact that it is known that the patterns of diet, PA, sedentary behaviours, and sleep may also be contributing to the high prevalence of overweight and obesity (130). Research by the Lancet commission on adolescent health and well-being (39, 53) and the PA Series Working Group (115) support this focus on adolescent health, which also draws attention to a serious dearth of data from Africa despite the continent's disproportionate burden of NCDs. Considering the fact that many teenagers, especially young women may still lack independence from their home contexts is particularly significant since it may influence their ability to adopt health behaviours choices to improve preconception health (122). Therefore, it is essential to conduct this series of studies in order to understand the barriers such as the obesogenic environment that influence SA's young adults' health-related behaviours that could negatively impact on preconception health, how they intersect to influence behaviours, and identify levers to intervene and improve their health behaviours and, ultimately, preconception health.

1.3.7 Pregnancy, preconception health, adolescent dietary and lifestyle behaviours

The Global Strategy for Women's, Children's, and Adolescents' Health (109, 110) and the first (131, 132) and second Lancet series on adolescent health (23, 39, 53, 133-135) have helped summarize the knowledge gaps and stress the importance of investments and interventions (135) for reducing adolescent preconception risk factors and improving preconception health. Observational studies show strong links between health before pregnancy and the health of the mother and child, with effects that can last for generations, however, awareness of these links is not widespread (133). Poor nutrition and obesity are common among women of childbearing age, and the differences between high-income and low-income countries have become less distinct with typical diets falling far short of nutritional recommendations in both settings and especially among adolescents (3, 15, 27, 63).

During pregnancy, many public health programs focus on risky behaviours like smoking and drinking (136). Numerous studies show that giving micronutrient supplements to pregnant women can rectify important nutritional deficiencies in the mother. However, the effects on the health of the child are unsatisfactory (137, 138). Still, more and more evidence shows that interventions that only focus on pregnancy can be ineffective and even stigmatizing (139). Comparatively few interventions have been made for preconception diet and lifestyle (133). Although it is true that women are participating in clinical encounters, it does not necessarily mean they are getting preventive care or advice on how to improve their health (140). This is despite the fact that it is widely known that pregnant women continue to face the same health risks they did before they became pregnant, including substance abuse, poor nutrition, and long-term health problems resulting in an intergenerational transfer of metabolic disease risks, especially in low-income communities (81, 86, 136). Evidence shows that maternal and paternal nutrition are important components of a life-course approach to health that play a role in perinatal health in the context of women's overall health (141-143). The risk of NCDs in future generations, including obesity and chronic conditions, is on the rise, and there is mounting evidence that this trend can be slowed by intervening in the preconception period (6, 28, 48). Life-course risk factors, such as a mother's diet and body composition before and during pregnancy, have been linked to later-in-life mortality and morbidity (28, 144, 145).

Researchers have also found that fathers health-conscious choices before and during pregnancy have a significant impact on the well-being of their pregnant partners and their children (146, 147). Despite this, studies show that many women, especially young women, do not think about or prepare for pregnancy (86, 148, 149). This could be the reason pregnant women often make poor dietary and activity choices, or it could also be the result of a woman's social circumstances (63, 121, 150). All these factors may have negative effects on future generations' health if healthy habits are not established before pregnancy (136, 139, 141). As such, this mounting body of evidence suggests we should devote more resources to addressing the obesogenic behaviours such as poor dietary and physical activity habits that contribute to obesity as well as other NCDs, which have the power to determine the course of this generation and, by extension, the future of humanity (7, 53, 132, 146). While preconception health has mainly been centred on the assumption that a woman is planning to become pregnant, evidence in LMICs such as SA shows that unplanned/unwanted pregnancy is prevalent particularly in young women (84, 148). The adolescent period presents a significant opportunity to improve the maternal preconception period and the paternal influence on partner and offspring's health (141, 146).

1.7 Overall aim

This thesis's overall aim was to investigate the individual, household, and environmental factors that influence adolescents' dietary and physical activity habits and to identify ways in which these factors can be leveraged for interventions to better ensure the health of future generations, especially during the crucial preconception years.

1.7.1 Study Objectives

Four objectives emerged to achieve the above. The first objective (Paper 1—Chapter 3) was to determine whether household socioeconomic status (SES), dietary knowledge and patterns, and level of physical activity have a direct or indirect relationship with BMI in urban South African young women (18–24 years old).

The second objective (Paper 2—Chapter 4) was to explore young adults' barriers to healthy eating, physical activity, and the solutions to address these barriers with an intersectionality

perspective. The concept of intersectionality was employed to explain how individual, household, societal, and neighbourhood barriers to healthy eating and participation in physical activity interact, as well as their proposed solutions, to place emphasis on the reasons why they should be focused on simultaneously.

The third objective (Paper 3—Chapter 5) was to explore Soweto's young people's knowledge and perceptions of COVID-19 and its effects on their lives, including access to healthy nutrition and physical activity opportunities, and mental health, for over six months during the pandemic. The longitudinal qualitative design was useful for understanding what was salient to young South Africans and their experiences over a six-month period in order to better understand how teens behave during a global health crisis.

The fourth objective (Paper 4, Chapter 6) was to describe and compare nutrient patterns of urban adolescents and adults at three time points (baseline, 12-month follow-up and 24-month follow-up), evaluate if they changed over the 24-month period, and determine their relationship with adiposity (BMI).

1.7.2 Research Questions and Hypotheses

Research Question 1: Is the BMI of urban young women directly influenced by household SES, dietary knowledge and patterns, and level of physical activity?

Hypothesis: Household SES, dietary knowledge and patterns, and level of physical activity do not have an explicit influence on the BMI of urban young women.

Research Question 2: Are the barriers to healthy eating and physical activity and the ways to deal with them similar for young men and women in cities?

Hypothesis: The barriers to healthy eating and physical activity, as well as the solutions to these barriers, differ between urban young men and women.

Research Question 3: During the COVID-19 lockdown, did limited access to healthy nutrition and physical activity opportunities contribute to teenagers' mental health problems?

Hypothesis: Limited access to healthy nutrition and physical activity opportunities contributed to the mental health problems of young people.

Research Question 4: Are the nutrient patterns of urban adolescents over time comparable to those of adults, and are they related to BMI?

Hypothesis: The nutrient patterns of urban adolescents and adults are comparable over time and significantly associated to BMI.

Chapter 2: Methodology

This chapter discusses the context and methodology of the thesis, as well as any ethical considerations and data measurement and management strategies implemented. This series of investigations proposed four primary aims and two distinct but complementary methods of investigation. Each strategy includes a justification for why it is the optimal option for achieving the stated objectives. This resulted in a deeper understanding of the research question at hand and a larger body of evidence.

2.1 Study setting

This thesis had multiple objectives, each of which sought to characterize a different level. For instance, the first objective of the study was to determine whether the household SES, dietary knowledge and patterns, and level of physical activity have a direct or indirect relationship with BMI in young urban SA women. This was necessary in order to investigate the factors that influence the dietary and lifestyle behaviours of urban youth, and, in turn, adiposity and related literature, which helps to situate the significance of this thesis topic within the context of urban South Africa and to frame the subsequent objectives, which sought to focus attention on identifying individual, household, and societal factors influencing the health behaviours of young adults.

SA (Figure 6) is a SSA country with a middle-income economy and a projected total population of 60.6 million in 2023, 17.8 millions of whom are young adults (aged 18-34) (151). While GDP was estimated at $419 billion in 2021 (152), economic expansion has declined from 6.3% in the year 2020 to 1.3% in the fourth quarter of 2022 (153) due to a number of reasons, including persistent load-shedding (154), the COVID-19 pandemic (155), factional battles between leaders of the ruling political party (156), widespread corruption known as "state capture" (157), a lack of decisiveness and slow response from the government, and an inability to address pervasive inequalities (158, 159). The majority of young people in SA are either not in school, not working, or not employable as a direct result of these problems (160). Given SAs high youth unemployment rate (39.5%) (160) and widespread poverty, this could have devastating effects on the country's already strained health care system and its ability to provide its citizens with adequate and sustainable public health care leading to high mortality of young people (70%, adolescents aged 15 to 19 years) (Figure 7) (159-161).

Figure 6: *Map of South Africa.*

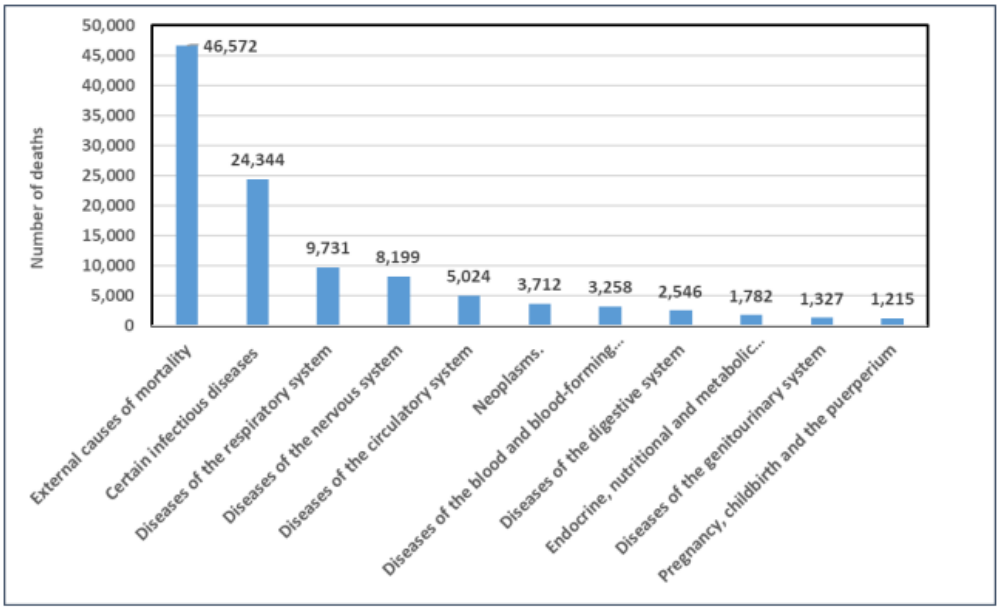


Figure 7: *Causes of adolescent mortality in SA 2008-2018.*

Approximately 15 kilometres from Johannesburg's central business district is the large urban area of Soweto, which is in the province of Gauteng (Figure 8).

Figure 8: *Map of Gauteng.*

Gauteng, is the smallest province in SA (162) in terms of land coverage, accounting for only 1.5% of the total land area of the country, is almost exclusively urban, has the highest total population (Figure 9) and of youth and adults aged 15 to 59 years (67.8%), increasing individual crime rates (29.5%), persistent food insecurity (43.6%), recorded higher proportions of adolescents with mental issues in 2019 (10.8%) and 2020 (10.7%) and among top 5 province with high teenage pregnancies in 2019 (13.7%) (151, 163, 164).

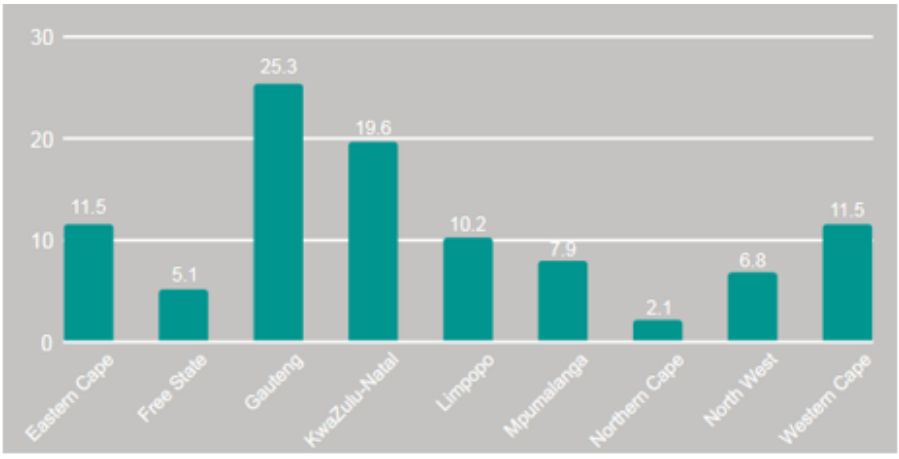


Figure 9: *Population proportions for each SA province.*

Soweto (Figure 10), originally an informal settlement for migrant mine workers and Black people displaced from other areas of Johannesburg during the Apartheid era, the name is thought to have been derived from the phrase "so where to?" Approximately 1.27 million

people (98.5%) live in this area of townships, making it the most densely populated region in the country (164, 165). It covers an area of 200 km^2.

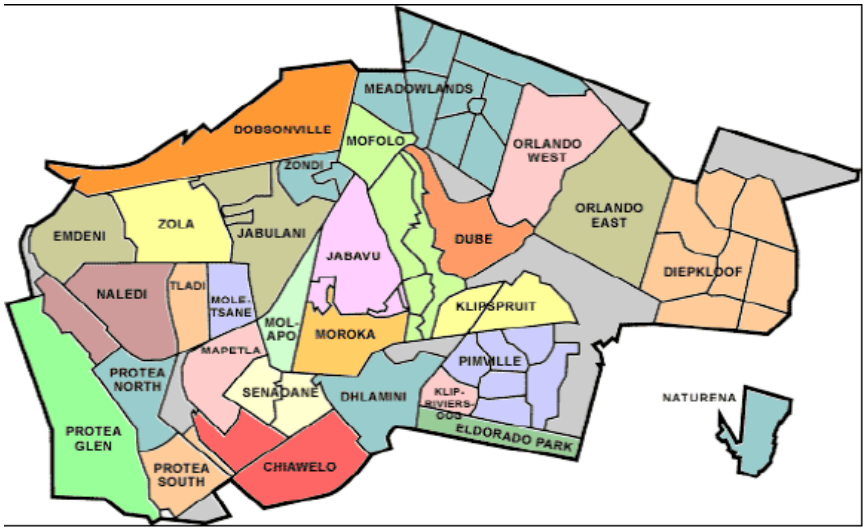


***Figure 10**: Map of Soweto.*

Despite the fact that South Africa has had a democratically elected government since 1994 the challenge of inequality still persists (166, 167). Even within Soweto, the wealth gap is glaringly obvious, with some areas boasting opulent mansions and others being slums where people live in makeshift corrugated iron shacks (Figure 11) (168).

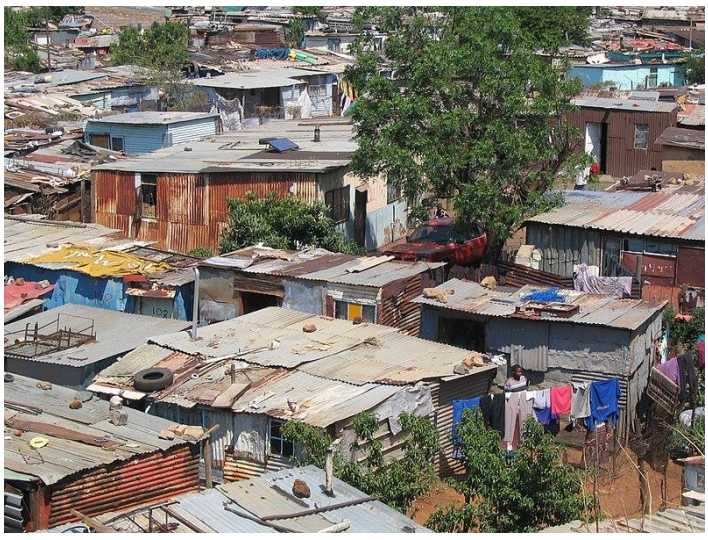


***Figure 11:** Basic housing in Soweto.*

Soweto is representative of the nutrition transition occurring throughout Africa, where rapid urbanisation has led to a preference for high-energy, Westernized diets (28). Research findings show that women in Soweto consume disproportionately high amounts of processed foods, sugary drinks, processed meats, and fast food linked with excessive weight gain, according to a previous study (28) (Figure 12).

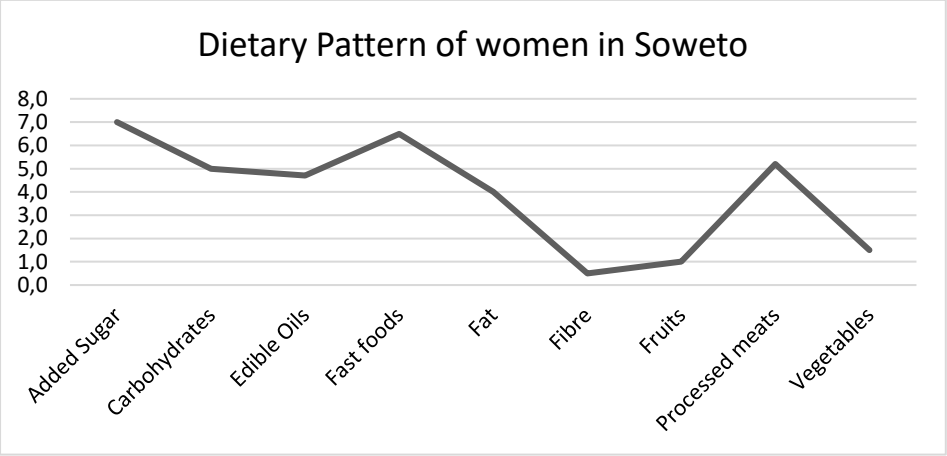


Figure 12: *Previously observed dietary pattern in women .*

Changes in the nutrition environment, rising rates of overweight and obesity (68% of women and 31% of men) (66), persistent infectious diseases like HIV/AIDS (40% of women and 27% of men), teen pregnancies (16% of women age 15-19), gender-based violence (21%), and emerging NCD burdens are disproportionately affecting young people, especially young women (15–24 years old) (40%), making preconception health especially important for this at-risk population (66). These problems are further exacerbated because of restricted access to health-related information and resources (169).

The aforementioned served as the underlying reason for conducting research into the individual, household, and environmental factors that influence the health-related behaviours of adolescents, specifically the diet and physical activity that were assessed for objectives 2, 3, and 4 of this thesis. Objective 2 concentrates on gathering perspectives through focus group discussions on the barriers to healthy eating and physical activity that urban Soweto young adults face within their living context, as well as the solutions that can be used to overcome these barriers from an intersectionality point of view. Objective 3 sought to explore Soweto

teen's knowledge and perceptions of COVID-19 and its effects on their lives, including access to healthy nutrition and physical activity opportunities, and mental health, for over six months during the pandemic. And objective 4 sought to describe and compare the baseline, 12-month follow-up, and 24-month follow-up nutrient patterns of urban adolescents and adults, evaluate if they changed over the 24-month period, and determine their relationship with adiposity (BMI).

2.2 Study design

I purposely designed my thesis to use a sequential mixed methods approach, which integrates quantitative and qualitative analyses, so that I could meet the four stated objectives of my research more effectively. Conveniently, the mixed-methods research strategy permits the collection of both qualitative and quantitative data, the use of both pre-planned and ad hoc research designs, the application of both statistical and content analysis to the collected data, and the generation of meta-inferences as answers to research questions. When trying to make sense of inconsistencies between quantitative and qualitative results, a mixed-method design can be extremely helpful. The findings provide a stronger, more all-encompassing body of evidence and a more comprehensive understanding of the research question. For example, well-done sampling techniques that focus on people, treatments, time points, and settings would give researchers many ways to make their findings more general and truer to the real world.

On the other hand, qualitative tools will make it easier to study context and change processes in more detail, paying close attention to specific and unique cases. The series of studies in this thesis therefore sequentially used quantitative and qualitative approaches to mitigate the disadvantages of both approaches and to compensate for their shared weaknesses. Consequently, the methods selected for this series of investigations were primarily influenced by the substantive research questions that arose, as opposed to methodological and epistemological concerns alone. I utilized three pre-existing data sources, including the "Birth-to-Twenty Cohort," the "Determinants of Type 2 Diabetes Mellitus" study, and the "Soweto household enumeration survey." I have gathered new prospective data that is quantitatively and qualitatively longitudinal and cross-sectional.

Table 1. *Distinct methods of the thesis.*

Objectives	Design	Population
1. The relationships between socioeconomic status, dietary knowledge and patterns, and physical activity with adiposity in urban South African women	*Quantitative * Cross-sectional	This study recruited 160 healthy and non-pregnant young women (of ages 18–24 years) from Soweto household enumeration survey database.
2. Exploring young adults' barriers to healthy eating, physical activity, and the solutions to address these barriers with an intersectionality perspective.	* Qualitative *Cross-sectional	30 young black (n=15 men and n=15 women) between the ages of 18 and 24 years were recruited and enrolled from the Soweto household enumeration survey database.
3. Exploring Soweto's young people's knowledge and perceptions of COVID-19 and its effects on their lives, including access to healthy nutrition and physical activity opportunities, and mental health, for over six months during the pandemic.	*Qualitative *Longitudinal	30 Black teenagers (16–21 years old; 15 men, 15 women) were recruited from the Soweto household enumeration survey database.
4. Describing and comparing nutrient patterns of urban adolescents and adults at three time points (baseline, 12-month follow-up and 24-month follow-up), evaluate if they changed over the 24-month period, and determine their relationship with BMI	*Quantitative *Longitudinal	This study recruited 750 participants. A random sampling of households in Soweto was conducted to recruit 250 adolescent (n=125 boys and n=125 girls) participants aged 13–17 years. In addition, the purposeful selection of 250 (n=125 men and n=125 women) middle-aged adults aged 45+ years from the "Determinants for Type 2 Diabetes Mellitus (T2D)" study and 250 (n=125 men and n=125 women) young adults aged 27 years old from the "Birth to Twenty" cohort study were used to make up the total of 500 adult participants.

In addition, each objective's methodology is described in detail in the subsequent empirical chapters that follows below (3 to 6).

2.3 Ethical approval

The Human Research Ethics Committee (Medical) of the University of Witwatersrand granted permission for the collection of data under the following ethics numbers: M171137, M190523, M170604, and M160604, which led to the four research objectives.

Part 2: Empirical chapters

"It is time that the adolescent health comes of age. Adolescent health is a smart investment: not only will it improve survival in the short term, it will bring benefits for future generations."

-*Valentina Baltag*

Chapter 3: Paper 1

Gudani Mukoma, Stephanie V Wrottesley, Juliana Kagura, Tolu Oni, Lisa Micklesfield & Shane A Norris (2022) The relationships between socioeconomic status, dietary knowledge and patterns, and physical activity with adiposity in urban South African women, South African Journal of Clinical Nutrition, DOI: 10.1080/16070658.2022.2076374 (Published online: 06 June 2022).

3.1 Introduction

The obesity epidemic continues to rise rapidly in low- and middle-income countries, particularly in Africa, despite the high prevalence of food insecurity and undernutrition (170, 171). Currently, SA has the highest obesity prevalence in SSA (172), with the latest national survey reporting a 68% prevalence of overweight and obesity in adult women, and 40% in young women between 15 to 24 years (173). Using data from the Birth to Twenty Plus cohort in Soweto, Nyati et al., (174) also reports this rise in combined prevalence from 11 years of age, reaching 46.5% in the 21+ years of age in urban young women. Alongside this, poor nutritional knowledge has also been reported in young South African women (175).

The role of a healthy diet and regular physical activity (PA) in the prevention of obesity and associated NCDs is well documented (176, 177). Research has shown that lifestyle behaviours, including diet, PA, smoking and alcohol intake, during adolescence are often maintained into adulthood, influencing the risk for obesity and NCDs (178, 179). Moreover, research data also shows that healthier diets are associated with higher SES levels, while there is data to support poorer diets due to choice-constrained conditions, along a continuum representing factors over which the individual has little or no control, to those for which they have greater agency (180, 181). Since 1994, the consumption of meat, fats and oils, sauces, dressings and condiments, sweet and savoury snacks and soft drinks has increased in SA by more than 30% (182). High consumption of these foods has been associated with weight gain, higher obesity prevalence and other NCDs in adults and children (182).

Upstream factors such as household SES, mass media exposure and urbanization, are well described as important determinants of shifting dietary habits and physical inactivity, and therefore associated with risk of NCDs and premature mortality (107, 176, 183-185). This is

exacerbated in African countries that are rapidly urbanizing with increased access to energy-dense, low quality foods, alongside persisting food insecurity (186). Understanding the complexity of the interaction between household SES and health behaviours is necessary to inform public health intervention development to curb the rising obesity prevalence in African women in poor urban settings. The aim of this study was to examine the relationship between household SES, dietary knowledge and patterns, and PA level, with adiposity (BMI) of urban South African young women.

3.2 Materials and Methods

3.2.1 Study Sample and Design

This cross-sectional study was conducted at the South African Medical Research Council (SAMRC)/Wits Developmental Pathways for Health Research Unit (DPHRU) at the Chris Hani Baragwanath Academic Hospital (CHBAH) in Soweto. CHBAH is one of the largest hospitals worldwide and a public tertiary care institution that serves the low-income community of greater Soweto in south-western Johannesburg, South Africa. Soweto is one of the most well-known historically disadvantaged townships in South Africa known for its established communities, socioeconomic and cultural variations (187).

In 2019, as part of a larger package of work by the Global Diet and Activity Research (GDAR) Network, explained in more detail elsewhere (188, 189). A convenience sample of 160 black young women participants between the ages of 18 to 24 years were recruited from the Soweto household enumeration study (190), which included individuals and household data from more than 2000 households in Soweto. This enabled the identification and recruitment of participants from low and high-income households to ensure socioeconomic diversity (188). All participants gave written informed consent prior to participating in the study. The Human Research Ethics Committee (HREC) of the Witwatersrand University, with ethics numbers M171137 and M190523 granted ethical approval.

3.2.2. Anthropometry

All measurements were performed with participants in light clothing and without shoes. The participant's height (in mm) was measured using a Seca 213 portable stadiometer and converted to meters (m). Body weight was measured to the nearest 0.1 kg using a portable electronic bathroom scale. BMI was calculated as weight in kilograms (kg) divided by height $(m)^2$.

3.2.3 Socio-economic status

Questionnaires were completed via interview by trained research assistants. To assess the household SES, an asset index was determined and consisted of the sum of assets out of a possible 13 (electricity, refrigerator, stove, vacuum cleaner, washing machine, digital satellite TV, digital optical disc (DVD), car, landline, mobile phone, personal computer, internet). Young women with 1-7 assets were categorized as having a lower household SES index and those with 8-13 assets as having a higher household index category. This index has been described as a useful method for determining socio-economic status in this setting (191). All young women were required to report the highest level of education that they had successfully completed, and this was then categorized into some secondary education, completed secondary education, and tertiary education.

3.2.4 Dietary assessment

A standardized quantitative food frequency questionnaire (QFFQ), designed for the South African population was used to collect dietary intake data. This tool was developed by the SAMRC using results from dietary surveys in both urban and rural areas since 1983 (122). The QFFQ is made up of 214 food items that are representative of foods consumed by at least 3% of the population. This tool has been piloted and utilized extensively in Soweto as described elsewhere (28, 192, 193). In order to complete the QFFQ, trained research assistants used high quality photographs of food items to trigger participants' memories of all foods and beverages consumed during the previous seven days. The participants were asked to arrange the cards into three piles: foods eaten in the last seven days, foods eaten occasionally, or foods never eaten, and this was recorded. The QFFQ was then administered and took approximately 40-50 minutes to complete. In the case of food items that were consumed in the past seven days, additional data on the frequency and quantity of consumption was recorded. Portion

sizes were estimated using a combination of high quality two-dimensional drawings of foods, household utensils and three-dimensional food models which have been described and validated by Steyn et al. (194). Estimated portion sizes were converted to grams to allow for calculation of the participant's average intake of the food items consumed over the previous 7 days. The QFFQ was captured and managed online using REDCap electronic data capture tools hosted at the University of the Witwatersrand (195).

The nutrition knowledge questionnaire was adapted from previously validated instruments (196, 197), but has not been used in this context previously. Nutritional knowledge was determined using a summative score consisting of 4 knowledge components - knowledge of advice from experts, classification of food groups, choosing foods, and diet related health problems, and was considered adequate or good when it was ≥32 out of the maximum score of 63. Inter-item analysis was used to assess internal consistency (Cronbach alpha = 0.80).

3.2.5. Physical Activity and Sedentary Behaviour

The Global Physical Activity Questionnaire (GPAQ), developed for global physical activity surveillance, was completed via interview to obtain self-reported physical activity [21]. Total MVPA in minutes per week (minutes/week) was calculated by adding occupation, travel-related and leisure time moderate and vigorous intensity physical activity. MVPA was considered sufficient if a participant met the WHO recommendation of ≥150 minutes per week (198).

3.3 Data analysis

Data were analysed for 160 young women with complete data using STATA SE 15.1 (StataCorp, College Station, TX, USA). Descriptive characteristics of the sample are presented as median (interquartile range) and percentages (%) for continuous and categorical variables, respectively. Study characteristics were compared between participants with low household SES index and high household SES index using the Kruskal Wallis rank test for continuous data and chi-squared tests for categorical data. Principal component analysis (PCA) was used to identify dietary patterns. This method groups variables, food items or groups based on the level of correlation with each other to form new linear components that reflect combinations

(patterns) of intake in a population. PCA was conducted on the weekly consumption of the food items listed in the QFFQ which were classified into 49 food groups according to their nutrient composition and usage. These groupings were based on those used and described extensively by Crozier et al. (199). PCA was applied using orthogonal (varimax) rotation and the Kaiser-Meyer-Olkin measure of sampling adequacy (0.65) and Bartlett's test of sphericity ($p < 0.001$) confirmed PCA to be an appropriate dimension reduction technique to apply in this sample. Eigen values, as well as their visual inflections on a Scree plot, and the total variance explained (percentages) were used to identify retained patterns. As described elsewhere, foods or food groups that had factor loading scores ≥0.3 on the PCA matrix reflected strong associations with principal components and these were used to name dietary patterns (200, 201).

Multivariate linear regression models were computed to assess the association between household SES index, age, education, nutrition knowledge score, western and mixed dietary patterns, and MVPA as predictors, and BMI as the outcome variable, for the whole group and then stratified by SES group. Collinearity between the variables was checked by calculating the variance inflation factor (VIF) with the highest VIF being recorded at 1.19. A VIF >10 is considered significant collinearity.

Structural equation modelling (SEM) analysis (Figure 13) was used to determine the direct, indirect and total effects of household SES, age, education, nutrition knowledge score, western and mixed dietary patterns and MVPA on BMI. To evaluate the best fitting model for our data, we reported goodness of fit indices including chi-squared test, root mean squared error of approximation (RMSEA), Tucker-Lewis index (TLI), Coefficient of determination (CD) and standardized root mean squared residual (SRMR). Statistical significance was regarded as a *p*-value less than 0.05.

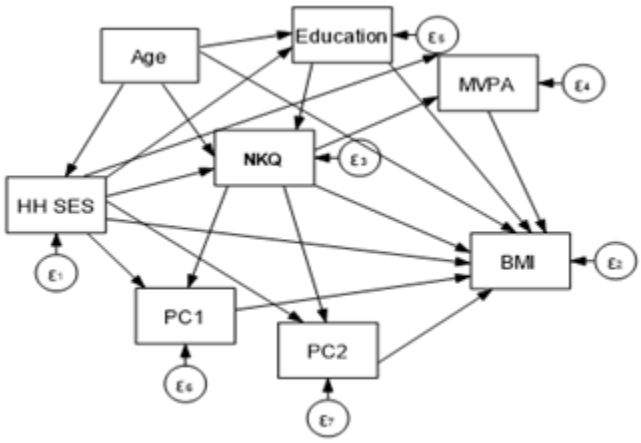


Figure 13: Conceptual model for the association between SES, age, education, nutritional knowledge (NKQ), Western dietary pattern (PC1), Mixed dietary pattern (PC2) and MVPA with BMI among young women.

3.4 Results

3.4.1 *Descriptive statistics of young women living in Soweto*

The study included 160 urban Black young women with a median age of 21 years. Overall, 46.6% of participants were overweight or obese, with the prevalence being slightly higher in women from high SES households (48.4%) compared to their low SES counterparts (44.8%). More than half (53%) of the women had poor dietary knowledge. In contrast, young women from households with a low SES (range= 163; 840 min/week) spent significantly more time engaging in MVPA compared to their high SES counterparts (range= 105; 540 min/week) (Table 2). The top ten most frequently consumed food items data show little variation in consumption frequency between young women from households with high and low SES index in most of the food items consumed but modest differences in fruits and vegetables intake. Cooking oils, vegetables and sugar were the top three most frequently consumed foods in both low and high household SES groups. However, the data shows large differences in consumption of white bread and carbonated soft drinks which was at least 4 times per week in young women from households with low SES index compared to 0 in young women from households with high SES index, and then consumption of red meat and soup powder, condiments and sauces was at least 5 times per week in young women from households with high SES index compared to 0 in young women from households with low SES index (Figure 14).

3.4.2 *Identification and description of depicted dietary patterns*

Two distinct dietary patterns were extracted from the PCA, which together explained 32.9% of the variation in food intake. The first principal component (PC) was characterized by high factor loadings for sugar (0.829), tea and coffee (0.722), cooking fats (0.517), full-fat milk (0.444), breakfast cereals (0.431), red meat (0.407), vegetables (0.371), soup powder, condiments and sauces (0.365), processed meat (0.351), brown whole meal bread (0.336) and fruit juice (0.336) and was labelled the "Western" dietary pattern (19.8% variance). The second PC had high factor loadings for processed meat (0.559), red meats (0.558), fruits (0.516), vegetables (0.402), yoghurt, buttermilk and Maas (0.336), cakes and biscuits (0.335), rice and pasta (0.326), soup powder, condiments and sauces (0.304), and fruit juice (0.301) (13.2% variance). This PC was labelled the "Mixed" dietary pattern (Table 5 Supplementary).

3.4.3 *Multivariate linear regression analysis showing correlates with BMI*

Overall, age was positively associated ($p \leq 0.001$), and the **"**Mixed" dietary pattern was negatively associated ($p<0.05$) with BMI. Among young women from households with a low SES index, the "Mixed" dietary pattern ($p <0.05$), and MVPA ($p <0.05$) were inversely associated with BMI. For those with a high household SES index, only age ($p <0.05$) was associated with BMI (Table 3).

3.4.4 *Structural equation modelling for the direct and indirect effects of household SES, age, education, dietary (knowledge and patterns), and MVPA on BMI*

The structural equation model (SEM) for the direct and indirect effects of household SES, age, education, dietary knowledge, the Western and Mixed dietary patterns and MVPA on BMI is presented for the overall sample in Table 4 and Figure 13. The model showed a good comparative fit index (CFI) of 0.96 and a good Standardized root mean squared residual (SRMR) of 0.05. The SEM showed that age (95% CI 0.19; 1.03, $p<0.01$) had a direct effect on BMI. The "Mixed" dietary pattern and MVPA had direct inverse and significant effects on BMI. A unit increase in the "Mixed" dietary pattern was associated with 0.81 lower BMI kg/m^2 (95% CI = -1.54; -0.08), while ≥150 minutes MVPA per week was associated with almost a 2 lower BMI kg/m^2 (95% CI = -3.48; -0.41, $p<0.05$).

Table 2. *Descriptive characteristics of young women living in Soweto*

Participants characteristics	Total n=160	Low household SES index n= 67	High household SES index n= 93	p-value [a]
Age (years)	21 (20; 23)	21 (20; 23)	21 (19; 22)	0.31
Height (m)	1.59 (1.55; 1.64)	1.59 (1.56; 1.64)	1.59 (1.54; 1.62)	0.23
Weight (kg)	62.2 (50.8; 75.2)	61.7 (50.1; 75.9)	63.1 (52.2; 73.3)	0.78
BMI (kg/m^2)	24.1 (21; 28.8)	23.7 (20.6; 28.8)	24.70 (21; 29.50)	0.46
BMI Classification n(%)				
Underweight (<18.4 kg/m^2)	18 (11.2)	8 (11.9)	9 (9.7)	0.95
Normal (18.5-24.9 kg/m^2)	67 (42.2)	29 (43.3)	39 (41.9)	
Overweight (25-29.9 kg/m^2)	40 (24.8)	16 (23.9)	24 (25.8)	
Obese (>30 kg/m^2)	35 (21.7)	14 (20.9)	21 (22.6)	
Household SES index (sum of assets)	8 (7; 10)	6 (5; 7)	9 (8; 10)	≤ 0.001
Highest level of education n(%)				
Some secondary education	33 (21)	15 (22.4)	19 (20.4)	0.69
Completed matric	92 (57.4)	36 (53.7)	56 (60.2)	
Tertiary	35 (21.6)	16 (23.9)	18 (19.4)	
Nutritional knowledge score	32 (28; 35)	31 (26; 35)	32 (28; 35)	0.10
Nutritional Knowledge n(%)				
Good	75 (46.9)	35 (52.2)	40 (43)	0.24
Poor	85 (53.1)	32 (47.8)	53 (57)	
Total MVPA (minutes/week)	310 (105; 660)	390 (163; 840)	240 (105; 540)	0.05
PA levels n (%)				
Not meeting recommendations	68 (42.5)	30 (44.8)	55 (59.1)	0.62
Meeting recommendations	92 (57.5)	37 (55.2)	38 (40.9)	

Data are summarized as median (IQR) or n (%); recommended MVPA is ≥ 150 min/week, MVPA= moderate vigorous physical activity; Good nutritional knowledge is ≥ 32; [a] Kruskal-Wallis test (continuous variables), Chi2 test (categorical variable

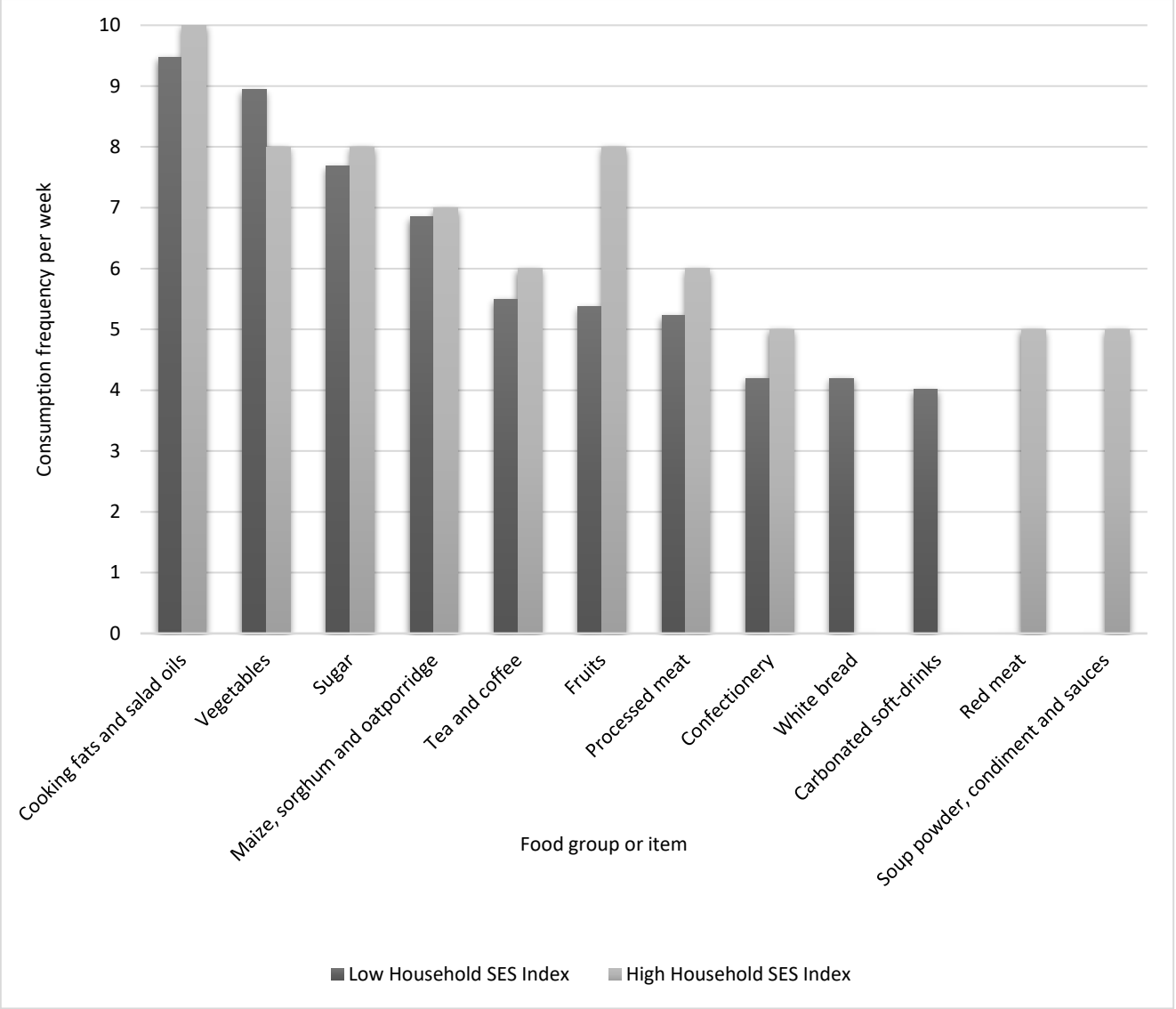


Figure 14: *Top 10 most frequently consumed foods by young women (low vs high household SES index).*

Table 3. *Multivariate linear regression coefficients for BMI among young women.*

	Total	Low household SES	High household SES
	B (95% CI)	**B (95% CI)**	**B (95% CI)**
Age (years)	0.62 (0.10; 1.15) *	0.41 (-0.25; 1.06)	0.56 (-0.01; 1.12) *
Education level	-0.83 (-1.82; 0.12)	-0.55 (-2.06; 1.05)	-1.20 (-2.72; 0.32)
Household SES index	0.06 (-0.31; 0.43)	0.03 (-0.88; 0.94)	-0.22 (-1.07; 0.63)
Nutritional Knowledge score	0.01 (-0.16; 0.18)	-0.13 (-0.34; 0.09)	0.10 (-0.10; 0.31)
Western dietary pattern	0.23 (-0.53; 1.01)	-0.41 (-1.85; 1.04)	0.35 (-0.61; 1.29)
Mixed dietary pattern	-0.77 (-1.54; 0.01)*	-1.52 (-2.78; -0.28) *	-0.29 (-1.28; 0.70)
Total MVPA (min/week)	-1.31 (-2.74; 0.11) *	-0.67 (-3.35; 1.93) *	-1.23 (-2.96; 0.49)

B= beta coefficient; CI= confidence interval; SES= socio economic status; MVPA= moderate-vigorous physical activity; min= minutes; Total R^2 =0.196; Low household SES index R^2 =0.139; High household SES index R^2 =0.143; * p≤0.05

Table 4. *SEM for the association between household SES, age, education, nutritional knowledge, diet and physical activity and BMI.*

Effect of:	**Direct Effect (95% CI)**	**Indirect Effect (95% CI)**	**Total Effect (95% CI)**
Household SES	0.07 (-0.34; 0.48)	0.06 (-0.06; 0.18)	0.13 (-0.24; 0.48)
Age	0.61 (0.19; 1.03) **	0.32 (0.01; 0.62)	0.63 (0.01; 0.91) **
Education	-0.83 (-0.89; 0.24)	0.70 (-0.12; 1.52)	0.10 (-0.27; 0.48)
Nutritional knowledge	-0.001 (-0.16; 0.18)	0.01 (-0.03; 0.06)	0.02 (-0.14; 0.18)
Western dietary pattern	0.49 (-0.29; 1.28)	-0.04 (-0.17; 0.08)	0.21 (-0.69; 1.13)
Mixed dietary pattern	-0.81 (-1.54; -0.08) *	0.11 (-0.07; 0.28)	-0.77 (-1.52; -0.02) *
MVPA	-1.94 (-3.48; -0.41)*	0.11 (-0.13; 0.35)	-1.65 (-3.12; -0.12) *

All values are coefficients (95% confidence interval); Significance levels: * p ≤ 0.05; ** p ≤ 0.01; Fit indices: LR test of model vs. saturated: chi2(2) = 0.240, Prob > chi2 = 0.000; RMSEA = 0.04; CFI = 0.96 Comparative fit index; TLI = 0.86 Tucker-Lewis index; SRMR = 0.05: Standardized root mean squared residual, CD = 0.15 Coefficient of determination.

Discussion

We assessed the relationship between household SES, dietary knowledge and patterns, and physical activity level with adiposity of urban South African young women. The results have shown that age, the "mixed" dietary pattern, and MVPA have a significant relationship with BMI, however, these relationships only exist in young women from low SES households compared to those from high SES households. Age was positively and significantly associated with BMI overall. The "Mixed" dietary pattern with high intake of meats, fruits, vegetables, processed and energy dense foods and MVPA were inversely and significantly associated with BMI in young women from households with low SES index. Furthermore, using structural equation modelling, the results highlight that the direct and total effect of age (positive), the "Mixed" dietary pattern and MVPA (inverse) on BMI to be significant.

The association between age and BMI and the high prevalence of overweight and obesity in this study is in line with previous findings that show the prevalence of overweight/obesity to be increasing with age (202, 203). The overall reported prevalence of overweight/obesity in this study (46.6%) is similar to previous findings reported by Micklesfield et al., (203) and Munthali et al., (204) in a cohort of young women from Soweto and Agincourt of a similar age (18-21 years) which found a 46.5% prevalence of overweight/obesity.

While other studies in urban South African women by Gradidge et al., (205) and Munthali et al., (204) with the same cohort of women as Micklesfield study found associations between SES and BMI, this study's findings did not provide any substantial evidence of a direct or indirect effect. Instead, this study was able to provide evidence concerning the rising prevalence of overweight and obesity in South African young women from low and high SES groups. The "Mixed" dietary pattern and physical activity were found to have a direct association that could represent important targets for interventions. Previous research has linked the increasing prevalence of overweight/obesity with rapid urbanization and a nutrition transition characterized by increased consumption of western diets high in refined carbohydrates, added sugar and fat, as well as reduced physical activity, particularly in the African context (206). Although the "Mixed" dietary pattern found in this study has food items that had less nutritional value and high amounts of sugar and fats, it could be that the high

intake of fruits, vegetables and dairy products are potential drivers of the inverse association with BMI. However, similar to the “Mixed” dietary pattern reported by de Castro et al.,(207), this dietary pattern also be indicating a slower transition towards a high energy dense, micronutrient poor diet which is positively associated with elevated adiposity (208).

The relationship between physical activity and SES is complex (209, 210). Similar to other studies nationally and internationally (183, 211), our study shows that MVPA was higher (6.5 hours per week) in the low household SES group compared to the high household SES group (4 hours per week). While other previous studies found that lower SES status was associated with more sedentary activities such as watching television (212), our results found low household SES index to be associated with more time spent in MVPA, and an association between MVPA and BMI. The difference in these findings may be due to young women from households with lower SES index needing to assist more with household chores or walking more than their high SES peers. This further supports findings that indicated that individuals who maintain PA at recommended levels have smaller increases in BMI (203, 213). However, with almost 60% of young women in the high household SES group not meeting the ≥150 minutes per week as recommended by the WHO is a concern as it indicates poor levels of physical activity in this age group. By contrast, the direct, inverse and significant effect of moderate-vigorous physical activity on BMI supports the findings that PA can be incorporated when designing interventions to reduce the risk of overweight and high body fat percentage in a population (214).

This study does have some limitations. Our study was cross-sectional in nature, and as such, we cannot make robust conclusions about causality in the observed associations. Reported dietary data have limitations in misreporting, and they can vary by demographic variables such as age and level of education. Furthermore, our study only focused on young women, similar analyses are needed in young men to identify how sex may influence the relationships and help to target interventions to men and women in South Africa. The methods included clinical measures of BMI and although self-report measures of physical activity and sedentary behaviours were used, these methods have been validated in similar populations. The strengths also include the use of a validated QFFQ, and the PCA technique used for the present analysis to derive the dietary patterns is known for depicting real-world dietary behaviours.

Given that, individuals do not consume nutrients or foods in isolation, the elucidation of dietary patterns that describes the overall diet, alongside the assessment of structural effects of the different individual, socio-economic and lifestyle behaviours factors on adiposity are a particular strength of this study.

Furthermore, while the South African government interventions targeted to reduce the percentage of people who are obese or overweight by 10% in 2020, with current economic and nutrition transitions, it is critical that public health interventions foster greater intake of micronutrient-rich foods and maintenance of regular exercise. In a country that is already burdened by inequality, over population in urban areas, high unemployment rates, unhealthy lifestyle behaviours and poor health systems, effective multi-sectoral interventions are warranted. Furthermore, findings in this study can be useful in updating the current scientific knowledge – for example an update to the latest obesity prevention and control strategy will show if the set target was achieved, if the structural interventions to make healthier food and exercise choices were effective, and if household economic protection efforts such as access to farming land and better pay employment opportunities can improve the existing interventions. It will further enable the identification of gaps that still need to be addressed for the target to be achieved.

Conclusion

Our study suggests that it is important to consider the obesity risk of young women in the development of health promotion strategies in South Africa. We recommend that future dietary, physical activity, educational and promotional programs provide targeted strategies and guidelines suitable for young women with different SES backgrounds. In addition, our findings suggest that dietary education alone, while necessary, is insufficient to facilitate behaviours change. In combination with physical activity and dietary education, practical strategies are needed to motivate and facilitate behaviours changes that protect health in the short, medium, and long term.

Table 5 Supplementary. *Dietary patterns and factor loadings for young women living in Soweto.*

Food or Food group	PC1	PC2
	Western pattern	**Mixed pattern**
Sugar	**.829**	-.348
Tea and coffee	**.722**	-.541
Cooking fats and salad oils	**.517**	.224
Full-fat milk	**.444**	.112
Breakfast cereals	**.431**	.218
Red meat	**.407**	**.558**
Vegetables	**.371**	**.402**
Miscellaneous (soup powder, condiments, sauces, etc.)	**.365**	**.304**
Processed meat	**.351**	**.559**
Brown whole meal bread	**.344**	.094
Fruit juice	**.336**	**.301**
Potato	.293	.154
Eggs	.292	.204
Fruits	.223	**.516**
Cheese	.198	.259
Yoghurt, buttermilk, and Maas	.194	**.336**
Maize, sorghum and oat porridge	.191	-.075
Rice and pasta	.189	**.326**
Cakes and biscuits	.187	**.335**
Chicken and turkey	.134	.223
Carbonated soft drinks	-.125	.104
Confectionery	.121	.298
Fish	.097	.154
Crisps and popcorn	.089	.205
White bread	-.012	.000
Explained variance (%)	19.78	13.24
Cumulative explained variance (%)	19.78	32.92

Food groups or items with factor loadings ≥0.30 are shown in bold and were therefore used to describe each dietary pattern.

Chapter 4: Paper 2

Gudani G. Mukoma, Edna N. Bosire, Sonja Klingberg, and Shane A. Norris. "Healthy eating and physical activity: analysing Soweto's young adults' perspectives with an intersectionality lens", PLOS Global Public Health (Revisions submitted: 30 March 2023).

4.1 Introduction

40.5 million deaths worldwide in 2016 were caused by non-communicable diseases, 1.7 million of which were in people under 30 (215). The risk of death from NCDs was reported to be highest in low- and middle-income countries, particularly in sub-Saharan Africa (215) where NCDs like heart disease, stroke, and diabetes are becoming more prevalent causes of death and disability. By 2035, NCDs are anticipated to surpass infectious diseases as the main cause of death and disability (216, 217). Particularly concerning is the fact that in Africa, NCDs are affecting people at a much younger age (10 or more years younger) than in wealthier regions (218). This rising burden of NCDs is the result of risk factors that typically begin in adolescence, such as unhealthy diets, low PA, and sedentary behaviours, which are driven and exacerbated by urbanization, globalization, and commercial health determinants (2, 219-221). Furthermore, evidence suggests that the health risks are transferred to the next generation as well as affecting young people themselves (222). To prevent the development of NCDs in future generations, the 2016 Lancet Commission on Adolescent Health and Wellbeing recommended investing in prevalent NCD-related health behaviours among adolescents (7).

Young adults (18-26 years) in South Africa, particularly women, tend to lead more sedentary lives compared to their male counterparts, consume energy dense but micronutrient poor diets, and are at a high risk of developing NCDs much earlier in life (107, 223-225). Due to behavioural health risks, women were twice as likely as men to die from heart disease between 2012 and 2016 (14.7% vs. 7.1% respectively) (226). A recent survey in urban SA found that 46.6% of young women aged 18-24 years were in the body mass index-based categories of overweight or obese, and 42.5% of them did not engage in regular physical activity (63). On the other hand, consumption of foods (fats, oils, sauces, dressings, condiments, sweets and savoury snacks) associated with excessive weight gain has increased by 30% over the past

decade (227). While NCD risk factors are already high among young women, they significantly increase with age (228, 229). It is therefore important to support young people to adopt and maintain behaviours that minimize NCD risks, setting them on healthier trajectories. To do so, we must first gain an understanding of the contextual factors influencing their health beliefs, diet, and physical activity behaviours.

Individual characteristics, as well as social and physical environment factors such as home, family, peers, neighbourhood, school, and workplace, have been shown in studies to influence health beliefs and behaviours (97, 230, 231). From previous studies in urban SA, we learned that perceived affordability, taste, availability, individual preferences and family were significant determinants of food choices (96, 97, 232), while physical activity opportunities are constrained by a lack of facilities and safety concerns (97). These barriers have been shown to vary by age and gender among children and adolescents from high-income countries (233); however, evidence of how they differ among young adults is scarce. Changes accompanying the transition from adolescence to adulthood may make individuals more susceptible to emotional and social influences, making them more likely to favour behavioural choices that will benefit them now rather than in later life (63, 203, 224, 234). When this is compounded by the complexity of overcoming a multitude of barriers that arise from the social and physical environment, engaging in healthy behaviours becomes much more difficult (235). In contrast to other studies that have used socio-ecological models to demonstrate the different levels of influence on health-related behaviours, we used an intersectional lens in order to explore how young people face multiple connected barriers to healthy behaviours (236-239). The aim of this study was therefore to explore young adults' barriers to healthy eating, physical activity, and the solutions to address these barriers with an intersectionality perspective.

4.2 Methods

4.2.1 *Setting and study design*

This study was conducted at the SAMRC/Wits DPHRU at the CHBAH in Soweto. CHBAH is the largest hospital in Africa and the third worldwide; it is also a public tertiary care institution that serves the low-income community of greater Soweto in south-western Johannesburg, SA (97). Soweto is one of the most well-known historically disadvantaged townships in South

Africa known for its established communities, and socioeconomic and cultural diversity (240). However, while there is economic diversity in Soweto, poverty-related challenges are still a reality, including unemployment and food insecurity (241), and poor access to appropriate health services, especially for young adults (242).

Focus group discussions (FGDs) were utilized to collect data. We used a questionnaire to record the demographic information and anthropometric measures of participants. Participants were measured while wearing loose clothing and without shoes for all anthropometric measurements. A Seca 213 portable stadiometer was used to measure the participants' height (in cm), which was then translated to meters (m). Using a portable electronic bathroom scale, body weight was calculated to the nearest 0.1 kg. Weight in kilograms (kg) divided by height in meters (m^2) was used to determine BMI. These measurements were taken during the quantitative survey before the focus groups began.

4.2.2 *Participants and recruitment*

We purposively recruited and enrolled thirty Black men and women between the ages of 18 and 24 years from the Soweto household enumeration study database (190). The Soweto household enumeration database provided a sampling frame, which enabled identifying participants from both low and high-income households hence ensuring participants' socioeconomic diversity (188, 190). During recruitment, research assistants contacted prospective participants using the contact information provided on the enumeration study database inviting them to participate. They outlined the purpose of the study, as well as provided contact information in case more information was required. Research assistants at DPHRU collated the information on prospective participants who were then called back to make appointments. The recruitment of these participants was to form part of a larger package of work by the GDAR Network which started in the year 2020, explained in more detail elsewhere (188, 189).

4.2.3 *Theoretical framework*

The theoretical framework for this study is provided by an understanding of the Socio-Ecological model of health and the Theoretical Domains Framework (TDF) with an

intersectionality perspective, which shows that health-related behaviours are influenced by physical, biological and psychological, sociological, economic and cultural barriers (243-246). The foundation of this paper is the assertion that various barriers intersect to affect how health-related behaviours turn out, which is supported by both the social-ecological model of health and the TDF (243-246). We applied the intersectionality framework to comprehend how context influences the emergence of health problems in complex ways rather than reducing perceptions and behaviours to a single characteristic (244). To be more precise, we assessed different factors (personal, domestic, societal, and neighbourhood) that affect people's decisions and beliefs and induce behaviours (243, 244, 246). The intersecting rings of the model (Figure 15) illustrate how factors at one level intersect with factors at another level and influence behavioural outcomes. For instance, easy access to unhealthy food may intersect with a person's taste preference, leading to higher consumption of unhealthy foods. In recent years, there has been a strong push to develop environmental level health interventions such as school-based physical activity promotion to expand beyond programs that exclusively target individual level behaviours (247). Whilst research has extensively reported on the importance of households, parental feeding practices and family influence in shaping childhood health habits (248), the same cannot be said about adolescents and young adults (249). As young adults transition to adulthood, the personal, social, and environmental changes that transpire such as moving out of their home, studying, cohabitation with peers or partners, and starting a new job have a great influence on their lifestyle behaviours choices that are linked with poor diets and rapid weight gain (250). Therefore, interventions that target the environment may be more efficient and potentially more effective than individually targeted interventions because they are designed to change the context in which people live and work to create conditions supportive of healthy behavioural choices (245). In addition, although working with individuals to affect behaviours is difficult and resource consuming, interventions that influence policies and group-level behaviours can in turn affect individual-level behaviours among a much larger group of people and thus be more resource efficient (245, 251). Thus, health interventions targeting young men and women should consider all intersecting elements [33].

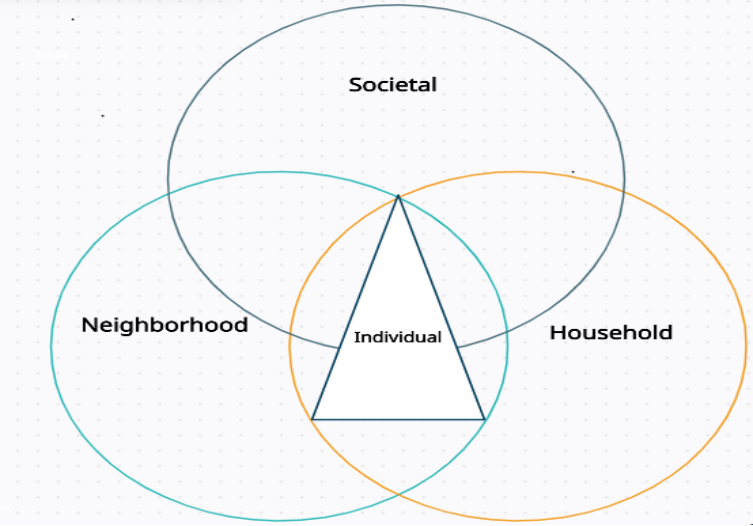


Figure 15: *A conceptual diagram showing distinct factors intersecting to influence young individuals' health related behaviours.*

4.2.4 *Data collection*

The data were collected during May and June of 2020. The FGDs were conducted in English by two experienced multilingual qualitative researchers one facilitator and one note taker, with participants using vernacular where necessary. All FGDs were held remotely due to the COVID-19 pandemic and the necessity to ensure the safety of our participants. A day before the FGDs, all participants received a one-hundred-rand airtime recharge voucher to cover internet costs. Across all four FGDs, a topic guide (Appendix J) was used to elicit discussions around perceived barriers and solutions to healthy eating and physical activity. A total of four FGDs were conducted, each comprised of 7-8 participants, and lasted between 45–90 minutes. The groups were divided by gender, with two groups made up of young men and two groups made up of young women (all aged 18–24 years). All FGDs were audio-recoded with participants' permission to record. The FGD sessions were meticulously documented, including observations. Audio recordings were transcribed verbatim and, when necessary, translated into English. All participants provided an electronically signed informed consent form before taking part in the study. The Human Research Ethics Committee (HREC) at Witwatersrand University granted ethical clearance, with ethics number M190523.

4.2.5 *Data analysis*

Data were analysed through thematic analysis (252, 253) with the help of the qualitative analysis software MAXQDA 2020 (version 20.4.2). Initially, data familiarization was done by the first author, which involved checking transcripts and repeated reading of transcripts. Thereafter, coding, initial themes, reviewing themes, defining and naming themes, and finalizing the analysis followed (254). Other authors were asked to review the initial themes; the reviews were used to refine the key themes until an agreement was reached. The data were coded and analysed using a combination of deductive and inductive approaches. The deductive approach was based on pre-identified themes that focused on the research question, while the inductive approach was used for all themes generated from the transcripts and field notes (253). This process enabled an interpretation of young adults' perceptions of various barriers to healthy eating and physical activity, and specific solutions to address these barriers. The key identified domains in relation to barriers and solutions to healthy eating and physical activity are described in the results section.

4.3 Results

4.3.1 *Sample characteristics*

The analysis included a total of 30 participants. The average age of the men was 21.5 years, that of the women 20.5 years. Compared to the young women (46.7%), more than half of the young men (53.3%) had completed grade 12 or high school. Only 3.3% of the participants had a university degree (Table 5). We present our findings from thematic analysis under the following four domains and nine main themes (in brackets): (1) Individual level factors (comprehension of health concepts and their interrelations; inability to apply nutrition knowledge to action; personal circumstances influence eating habits; not motivated enough to be active); (2) Influence at the household level (priority is for everyone to eat; immersed in household chores, no time for exercise); (3) Social influences (eating healthy means sickness) and (4) Influences by neighbourhood environment (junk food is inescapable, it’s everywhere and cheap; no gyms, exercising outside is unsafe). Additional extracts of participants' views can be found in (Table 6).

Domain 1. Individual level factors

Comprehension of health concepts and their interrelations

In the various group discussions, young adults displayed a basic understanding of health concepts and their interrelationships. They described health as a daily process involving routine check-ups, sufficient sleep, a healthy and balanced diet, and physical activity to promote or maintain overall well-being. *"Health is how you take care of your body everyday like seeing the doctor to check BP [blood pressure] and with the kind of food that you eat like veggies and gym and the time you sleep. It is the wellbeing of your whole body." (G2 men).*

When talking about nutrition, many young adults indicated that nutrition is about the foods people eat, which can be good or unhealthy. This in their opinion meant that nourishment could be both good and ill. Following a specific dietary plan that included eating fruit and foods high in protein and vitamins was generally recognized as good nutrition; *"[Nutrition is] a diet with proteins and vitamins that a person should follow like eating fruit and eating vegetables to stay healthy." (G3 women).* Good nutrition is important for healthy growth, a robust immune system and a "sharp mind" [cleverness and quick thinking] according to participants' views; *"Food that helps our body in terms of growing strong and healthy, and also having a strong immune system and sharp mind". (G1 women).* On the contrary, eating a modest amount of unhealthy food (referred to as "junk") was not considered a health risk by some young people, but eating too much of it was: *"I believe it is about how you eat the junk that is bad. If you have too much of junk food your health is going to be bad. But if watch what you eat then it's not bad." (G1 women).*

In the discussions about physical activity, the young adults mostly defined it as participation in daily planned and organized exercise routines or sporting activity; *"Physical activity is part of our day-to-day life. It can be when you wake up in the morning take a walk or jog, play soccer or go to gym." (G2 men).* Some of the reported benefits of physical activity included strengthening muscles, maintaining good posture and preventing disease, especially heart disease; *"Physically activity, we also need that because that strengthens the muscles which ensures healthy posture and prevents diseases." (G3 women).* However, the young adults did not see unstructured and unplanned tasks such as cleaning, cooking or laundry as physical activities, but rather as barriers, that takes up a large part of their daytime and leaves them

no time for exercise; *"I'm always busy like cooking and cleaning you know house duties and get tired so where do I get time to exercise." (G3 women)*.

In many cases, young adults mentioned that physical inactivity was associated with obesity burden and increased risk of NCDs. *"[high obesity risk is] when you are a couch potato [always sited] and don't exercise you gain fat…... you easily get sick with BP [high blood pressure] and heart problem when fat." (G4 men)*. Physical activity was recognized as the only option for maintaining good health. From participants' narratives, physical activity is a more effective means of controlling obesity and preventing diseases than diet; *"Even if you eat junk foods, you can be healthy and safe from obesity and diseases if you get exercise." (G4 men).* In several instances, participants also acknowledged that genetics is a factor contributing to the burden of obesity *"Sometimes the obesity is taken from other people in your family." (G4 men)* demonstrating a knowledge of risk factors outside their control.

Further, in the discussions, participants generally agreed that obesity meant a large amount of fat in the body that causes NCDs and could lead to death: *"[Obesity is] A drastic amount of fat in a human body. It can actually kill you as it brings heart problems and high BP." (G3 women)*. Undoubtedly, young adults recognized obesity as a significant burden in their communities, but they believed that obesity had been normalized, as even those affected perceived it as a signal of contentment rather than a health risk. *"Yes, obesity is a problem where I live, but many people that are fat are fine with that and say it shows they don't have problems [social and financial]." (G3 women)*.

Inability to apply nutrition knowledge in practice

Across all FGDs, most participants expressed that they did not know how to translate their knowledge about nutrition and physical activity into healthy behaviours; *"The thing is we don't know a way to use this knowledge of how healthy foods are good to our body, at the same time our places [home and neighbourhood] make it hard to do exercise." (G2 men).* One proposed solution to address this barrier was to provide health education in local languages, covering topics such as nutrition and physical activity through community TV and radio stations, social media platforms (WhatsApp, Facebook, and Twitter) and integrated into school lessons, especially at the primary level (grades R-3). This solution, in the participants' opinion,

is beneficial as it targets more than one barrier and considers language, outreach and accessibility issues that they have already encountered in other educational programs:

"We can start using TV or radio programs in the community to teach about healthy food and physical activity. Also, periods in primary classes like grade R or all lower classes can also teach what is obesity in our language and what are the effects of obesity and what to do to avoid it instead of just saying we need to eat healthy and exercise." (G4 men).

Personal circumstances influence eating habits

From participant discussions, it appeared that their basic understanding of health concepts, especially nutrition and physical activity, did not translate or influence an intent to engage in healthy behaviours. In all FGDs, participants admitted that their personal preferences, such as the taste of healthy foods, addiction to junk food, price and convenience of unhealthy foods were the main drivers to unhealthy eating patterns. In other cases, young people mentioned that they were able to eat both healthy and unhealthy foods, depending on circumstances such as affordability, taste and weather. For example, some reported that certain foods, such as those high in fibre, were of great benefit in cold weather. *"I do eat fruit and veg. I also eat Kota [A quarter loaf of bread stuffed with foods such as fried chips, pork sausage, cheese, polony, tomato sauce and mango atchaar] when it's cold days [because it is] high in fibre to keep warm." (G1 women).* To overcome these barriers, participants suggested practicing and promoting family meal sharing, as they recognized that time as an excellent opportunity for parents or adults in the family to teach the young one's about healthy eating. *"We all eat together in my family; we eat the same food. I am forced to eat the greens I mean veggies like cabbage and spinach, [that] mom cooks a lot." (G2 men).*

Not motivated enough to be active

Further in the discussions, participants cited personal feelings such as laziness, discomfort, and the monotony of exercise as the main reasons that prevent them from engaging in physical activity. *"I do know about exercising just that I just don't want to exercise, it is boring and the pain, no." (G2 men).* Some participants expressed interests in PA engagement; however, a lack of motivation was a barrier to their participation. *"In your back yard you are required to do the exercise alone and you are discouraged." (G3 women).* Getting external

motivators was proposed as a solution that could influence physical activity participation. According to participants, exercising with family or friends, or even joining a community club, might provide good motivation and promote regular participation in physical activity. *"I sometimes exercise with my friend in the morning and with my two older brothers in evenings. They make it fun and safe to exercise, I never miss." (G1 women).*

Domain 2. Influence at the household level

Priority is for everyone to eat

Some young adults' expressed a desire to lead a healthy lifestyle, but family and domestic barriers such as the inability to make decisions on what food to eat at home, limited food options due to household size, poverty and lack of family support to eat healthily were the main barriers that always put a halt to such a thought; *"The household where I live is poor, only mom works, I think I like to live healthy but they can't afford to buy healthy foods just for me alone." (G1 women)*. At this point, they declared that there was nothing else to do; moving away from home to become independent was the only solution to overcome these barriers. For them, independence meant taking control of their lives and deciding for themselves what they consume; *"Like when you start having your own place, you start buying groceries for yourself." (G4 men).*

While being independent was one of the proposed solutions to unhealthy eating, discussants argued that young children who are heavily dependent on their parents or relatives are a greater concern as they cannot make this choice of moving out of the family. They commented on how providing unhealthy foods to young children with the notion that it is an effective way to pamper them increased their likelihood of health issues. Participants noted that many young children grow up believing that eating unhealthy foods is a form of self-indulgence because they have learned it at home; *"Small children are growing with obesity because of the junk like KFC they [caregivers/parents] provide to them, they believe in spoiling [a nice treat] them with that KFC." (G1 women).* To overcome this barrier, the young adults indicated that practicing and teaching healthy eating at home is a much more viable strategy that can reduce the risk of premature mortality and diseases caused by eating poor quality meals from

an early age. *"We should teach the young ones at home first about how do we eat healthy so they won't fall in the trap of eating junk food that causes diseases that can kill them later." (G2 men)*.

Immersed in household chores, no time for exercise

Discussions around physical activities in the context of other everyday activities at home were also extensively noted. Our findings show that men and women face different challenges regarding physical activities within the home. In all FGDs, young adult women reported that they found it difficult to find time to exercise because of other household responsibilities such as washing or cleaning, helping to cook or caregiving roles. "I'm always busy like cooking and cleaning you know house duties and get tired." (G3 women). On the other hand, participants noted that men who could not exercise were just lazy, as they were not expected to do most of the household chores*. "I do know about exercising just that I'm lazy and just don't want to exercise, it is boring." (G2 men).* Becoming independent was their proposed solution to overcome this barrier because staying alone meant less chores. *"Staying alone is better, less duties and more time for exercising." (G3 women).*

Domain 3. Social influence

Eating healthy means sickness

Participants expressed their opinions on how peers, community members, and people in their communities have a general negative perception that eating healthy food is a sign of sickness. Eating vegetables and losing weight are seen as indicators of illnesses like HIV/AIDS or those struggling with NCDs like diabetes and hypertension. As such, gaining weight and consuming unhealthy foods like "Kota's" seemed ideal because it meant no judgment from others; *"You know you start to lose fat when you eat veggies right. The majority of them [peers/community members] believe if you eat healthy stuff like veggies right, it means that you are sick with things like AIDS, so I rather not eat." (G4 men)*. This was another way in which consumption of unhealthy food was normalized. Participants proposed that nutrition education that can be delivered through group discussions in the community can be a solution to create awareness and address this barrier. Accordingly, the discussions would encourage learning from one another, improving their understanding of the concept of healthy eating and associated

benefits; *"[The solution is]….make a group discussion with people and educate each other on nutrition and the benefits so they don't judge you." (G3 women).*

Domain 4. Influence by neighbourhood environment

Junk food is all over and cheap

Discussants reported that most street vendors and tuck shop sellers primarily sell unhealthy foods (commonly referred to as "junk") at lower prices. In addition, they noted that the high visibility of advertisements for unhealthy foods on main roads and neighbourhood streets exacerbates unhealthy eating habits. Based on their accounts, such visualizations, advertisements, and proximity to junk foods have influenced unhealthy eating especially amongst young people:

"*When it comes to changing the situation and eat healthy you can't because of the neighbourhood that you live around, we are exposed to junk food all over and it's cheap at the spaza [neighbourhood convenient tuck shop]. As you walk down the road all you see is a big billboard with coke, burger and chips so you always think of eating them." (G2 men)*.

These challenges led participants to propose setting up community gardens as a solution. They also mentioned a need to have more healthier food advertisements and awareness campaigns by health professionals about the dangers of unhealthy foods. Others argued that unhealthy eating should be considered as a pandemic, meaning government regulations on unhealthy food must be imposed in order to address these neighbourhood-level barriers; *"The government must address the nation like with Covid, address with a couple of food that is unhealthy and show healthy one, do same like hand sanitizers when you go to the shop, you know it is law." (G3 women).*

No gyms! Exercising outside is unsafe

While discussing about the environmental barriers to physical activity, it was noted that structural barriers, such as a lack of access to gyms or facilities for physical activity were among the most prevalent challenges that young adults' experienced; *"The fact is that we don't have places that we can go maybe to exercise after eating that Kota". (G4 men).* Participants narratives also revealed gender disparities, with women generally fearing for their safety and

encountering sexist remarks while exercising around the neighbourhood. *"In my area I can't even jog outside, there are always boys sitting at the corner saying embarrassing [sexist remarks] things about my body and their presence makes me feel uncomfortable, I don't feel safe." (G1 women)*. To address these barriers, participants proposed that young women should be encouraged to use their household backyards for physical activity. In addition, participants noted a need for the government to construct more facilities for physical activity in the community as well as employing security officers in community parks or having a community patrol to man security. This was said to be beneficial to all community members and may influence many young people to engage in physical activity.

4.4 Discussion

We set out to explore young adults' barriers to healthy eating, physical activity, and the solutions to address these barriers with an intersectionality perspective. Findings from the FGDs suggested that young adults in this urban South African township understood the significance of a healthy diet and physical activity and their relationship with health. However, they felt unable to put their knowledge into practice. Young adults in this study reported several barriers to healthy eating including taste and preference; a lack of autonomy on food decisions at home; negative beliefs about healthy foods; street vendors, advertisements and convenience stores that primarily sell unhealthy foods at lower prices. The commonly discussed barriers to physical activity were laziness; lack of facilities; and safety concerns when engaging in PA in their neighbourhoods.

Furthermore, we found that barriers to physical activity differed by gender. On one hand, young women found it more difficult to exercise because of housework chores, experienced sexist remarks or they had safety concerns. On the other hand, laziness, discomfort and the monotony of exercise and lack of exercise facilities demotivated young men to engage in physical activity. That said, young adults proposed a number of solutions to addressing these barriers and among these were: the practice and promoting family meal sharing; providing health education in local languages; becoming independent; getting external motivators; practicing and teaching healthy eating at home by adults; creating community gardens; more advertising of healthier foods; conducting more education campaigns by health professionals

on the dangers of unhealthy foods; establishing a community patrol forum; and building accessible physical activity infrastructure by the government.

Our findings are consistent with those reported in studies conducted with adolescents, young women, and adults (96, 97, 230, 232, 249-251). According to Ware et al., (232) in a South African study of urban young women, those who lived with their parents believed they had no influence over what was cooked and consumed in the home, and they perceived unhealthy foods to be cheaper, more accessible, and convenient because they were readily available. Among adults, Bosire et al., (255) reported that the stigma associated with being thin, which links it to conditions such as HIV/AIDS, has a negative impact on people's risk perceptions of being fat or overweight and makes them want to gain weight in an effort to escape this stigma. Wrottesley et al., (97) also reported on how adolescent girls were discouraged from exercising because they were concerned about losing weight or becoming too thin. Our findings, as well as those of previous studies, support our hypothesis that the young adults in this study are confronted with multiple barriers arising from the macro, and micro levels of society (256) (individual, family, community-level, grassroots institutions, and policies) that intersect to complicate their ability to engage in healthy behaviours, as shown in the conceptual diagram below (Figure 2), which illustrates how individual-level factors intersect with household-, neighbourhood-, and societal-level factors to influence behaviours (243). There is a need to understand the complex nature of these health inequities especially among young adults. Intersectionality is becoming more widely recognized as an important theoretical approach for studying health-related inequalities by highlighting the intersections of individuals' multiple identities within social power systems that exacerbate and reinforce experiences of poor health behaviours (243). To the authors' knowledge, this is the first study conducted in South Africa that analyses the barriers that hinder young adults from engaging in physical activity and eating healthily as well as the solutions to overcome these barriers using an intersectionality framework.

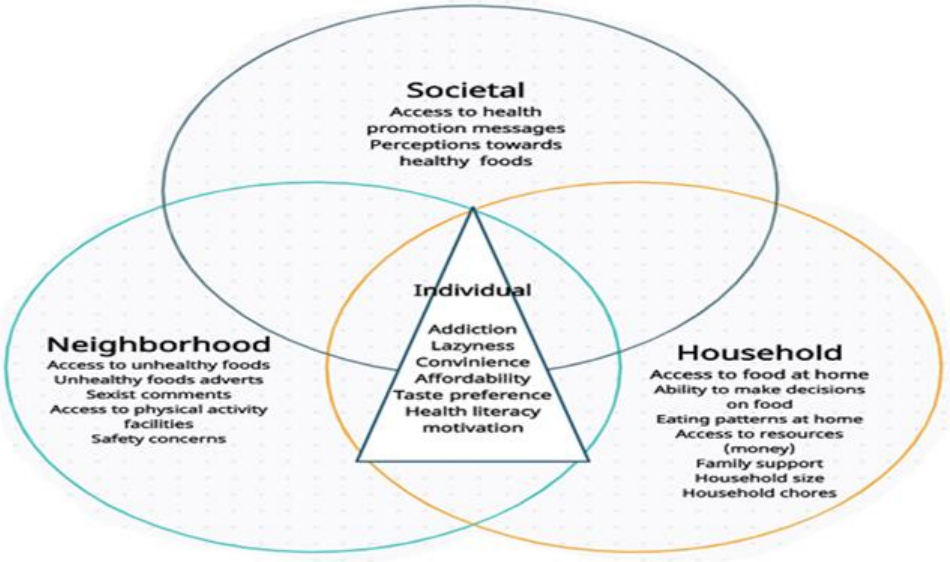


Figure 16: *Conceptual diagram showing the intersectionality between different multilevel barriers to healthy eating and physical activity influencing young adults' health related behaviours in the current study.*

Since the 1970s, neoliberal ideologies have grown in popularity and provide little support for addressing social determinants of health and wellbeing (257, 258). These ideologies emphasize individual attributes and choice as major drivers of health (259) and have led to a health promotion practice where interventions are implemented without taking contextual factors into account (260). Intersectionality goes beyond looking at individual factors like biology, socioeconomic status, sex, gender, and race. It focuses on how these factors relate to one another and interact with one another at various societal levels to understand how health is shaped across demographic groups and geographical contexts (261). In this study, intersectionality is employed to explain how individual, household, societal, and neighbourhood barriers to healthy eating and physical activity participation interact, as well as their proposed solutions.

As Louis Althusser pointed out, people (in this case, young adults) are conditioned to not only hear messages but also obey, comply, and live up to them (262). It is these context-based generated messages that address social ideas of race, class, gender, sexual orientation, age, and even physical characteristics often associated with disabilities or abilities in young adults (262). This means that healthy eating and physical activity perceptions are more strongly

influenced by the messages and meanings transmitted by meaning providers through social conditioning. Parents, friends, family and community members are among the people who can provide meaning, as do groups like those involved in school sports, churches or other religious institutions, and the media (visual and audio). Consequently, what young adults encounter in their families (lack of family support to eat healthily), neighbourhood or communities (easy access to unhealthy foods), and through media such as TV and music (advertisements of unhealthy foods) influence what they perceive as important and what they prioritize in a given society. At this point, intersectionality is when all these categories cross paths, revealing how inequities are shaped by interactions between different sites and spheres of power, which allows us to observe how these are all interconnected on a larger scale. Considering the intersectionality of social constructs, identities, and histories, we can see that there is even more connection between barriers to healthy eating and physical activity at the individual, household, social, and neighbourhood levels. To fully understand one, we need to understand the others.

Furthermore, applying an intersectionality lens in this study contributes to highlighting significant differences between young men and women that are often overlooked when addressing barriers to healthy eating and physical activity. In particular, it offers an explanation to how young men and women from lower socioeconomic groups might decide to exercise outside because they lack access to gyms, but only the young women would encounter sexism and concerns about safety. Because of this, young men have a slight gender advantage over young women when choosing to exercise on neighbourhood streets. Furthermore, this may also explain why some health education interventions are unsuccessful despite being recognized by research as a crucial component in the management and prevention of NCDs and their associated risk factors (260). For example, South Africa is a country with a wide range of linguistic and cultural diversity, yet health systems and public health interventions frequently use English as the main language for imparting health education, either orally or in handouts (263, 264). This is despite the evidence that shows there is a lack of health education among South Africans (63, 251, 265). In this case, it becomes apparent that English-speaking people from lower socioeconomic groups may have a greater advantage in accessing health services and comprehend how health education pertaining to nutrition and physical activity

can be applied than Africans who do not speak and understand English but have similar backgrounds. All these various aspects at different contextual levels interact and mutually inform one another and should be considered when implementing interventions or solutions that aim to influence healthy behaviours choices.

There are some limitations on the current study. The FGDs were held amid the COVID-19 pandemic using online video conferencing software rather than where participants lived and went about their daily lives, so we were unable to supplement the data obtained through the FGDs with additional sources of information like field observations. Some conversations had to be halted due to unstable network conditions. The young men and women who formed part of the discussions did not practice healthy eating or engage in regular physical activity; however, holding discussions with those who have adopted health related behaviours might have been of interest.

4.5 Conclusion

This study is important because it highlights the barriers to healthy eating and physical activity among young adults in Soweto and the proposed solutions. While some solutions have been proposed, young adults believe that they are not able to put them into practice. Our findings have also shown that young adults face a multitude of barriers that occur simultaneously at the individual, household, neighbourhood, and societal levels, making it difficult for them to make healthy behavioural choices. We advocate for young people to be involved in developing or designing solutions to promote health or influence healthy lifestyles. By focusing on the intersection or overlap of different factors, findings of this study could be used to influence health-related programs in Soweto and other similar contexts.

Table 6. *Characteristics of young adult focus groups discussion participants in Soweto.*

Variables	Total (n=30)	Men (n=15)	Women (n=15)
Mean age	20.9 (2.1)	21.5 (2.1)	20.5 (1.9)
Education level			
Secondary schooling	13 (43.3)	5 (33.3)	8 (53.3)
Passed grade 12	16 (53.3)	9 (60)	7 (46.7)
Tertiary	1 (3.3)	1 (6.7)	0
BMI Categories			
Underweight	1 (3.3)	1 (6.7)	0
Normal weight	21 (70)	14 (93.3)	7 (46.7)
Overweight	5 (16.7)	0	5 (33.3)
Obese	3 (10)	0	3 (20)

Table 7. *Young adults' understanding of health concepts.*

Domain	Theme	Excerpts from women	Excerpts from men
Individual level factors	***Comprehension of health concepts and their interrelations***	*"Health simply means taking care of your inner person like your body by eating healthy and exercising making sure you avoid stress." (*G3 women)	*"Health is how you take care of your body everyday like seeing the doctor to check BP and with the kind of food that you eat like veggies and gym and the time you sleep. It is the wellbeing of your whole body." (G2 men).*
	[nutrition is]	*"A diet with proteins and vitamins that a person should follow like eating fruit and eating vegetables to stay healthy." (G3 women)* *"Food that helps our body in terms of growing strong and healthy and also having a strong immune system and sharp mind". (G1 women)*	*"Eating fruit, mostly planted fruits and healthy food sort of like proteins and veggies." (G2 men)* *"I believe it is about how you eat the junk that is bad. If you have too much of junk food your health is going to be bad. But if watch what you eat then it's not bad." (G1 men).*
	[Physical activity is]		*"Physical activity is part of our day-to-day life. It can be when you wake up in the morning take a walk, do cleaning, play soccer or go to gym." (G2 men)*
	[Obesity is]	*"A drastic amount of fat in a human body. It can actually kill you as it brings heart problems and high BP." (G3 women)*	*"Obesity is a big problem because now you eat too much junk and you just get fat and very sick" (G2 men)*

Table 8. *Young adults' perceived barriers to healthy eating, physical activities and their solutions.*

Domains	Perceived barrier		Solution to perceived barrier	
	Theme	**Extracts**	**Proposed solution**	**Extracts**
Individual level factors	***Inability to apply nutrition knowledge to action***	*"The thing that we lack most is the knowledge of how healthy foods are important to our body and our life." (G2 men)*	Provide education programs on healthy eating in local languages	*"We can start TV or radio programs educating what is obesity in our language and what are the effects of obesity instead of just saying we need to eat healthy." (G1 women)* *"To change that thing we need to have programs even in schools where people will be taught the importance of eating healthy foods."(G2 men)*
	Personal circumstances influence eating habits.	*"When they cook healthy stuff, we don't eat the veggies because they taste bad." (G2 men)* *"The healthy food taste weird, not nice." (G3 women)*	Teach them young about healthy living	*"Teach them at a very young age to eat healthy and to go to gym exercise more. Because if you don't teach them at an early age they won't get used to it." (G2 men)*
		"We eat Kota; you don't need to wait for them to cook especially when it's cold days." (G1 women) *"Come on guys' fruit is money, veggies you also need more money, but Kota's are cheap." (G1 women)*	Government subsiding healthy food to make their access easy	*"Government must subsidize healthy food so that it can be affordable to those who want to eat healthy food but can't afford." (G3 women)*
		"If at home they don't teach you how to eat healthy you will never be healthy because you are going to get used to Kota's." (G2 men)	Eating together as a family	*"We all eat together in my family; I am forced to eat the greens I mean veggies like cabbage, spinach, and potato. But alone, I love to eat Kota." (G2 men)*
	Not motivated enough to be active	*"I do know about exercising just that I'm lazy and just don't want to exercise, it is boring." (G2 men)*	* Partner with friends or family * Forming community clubs	*"I sometimes exercise with my friend in the morning and with my two older brothers in evenings. They make it fun and safe to exercise I never miss." (G1 women)*

		"We have facilities to exercise in my community, for me is ignorance and laziness that is all." (G3 men)		*"I think it is much better if it is done in groups like start a community club to exercise same with soccer and netball." (G1 women)*
		"In your back yard you are required to do the exercise alone and you are discouraged." (G3 women)	Physical activity coaching	"We can have meetings with coaches like 3 days per week where there come coaches to motivate and they teach you to be physical activity and show some exercise." (G2 men)
Influence at the household level	***Priority is for everyone to eat.***	*"From childhood we grew up in an home that is not knowledgeable, we are just living our lives of eating junk food like Kota's." (G2 men)*	Being independent linked to freedom of food choice	*"Start taking responsibility of your life, when you start having your own place, you start buying groceries for yourself." (G4 men)*
		"I am the only one that wants to eat those healthy foods at home." (G2 men)	Teaching healthy eating at home	*"We should teach the young ones at home first about how do we eat healthy, so they won't fall in the trap of eating junk food." (G2 men)*
		"At home you can't tell them what to eat and what not to eat you see. You eat what is there" (G1 women)	Financial support linked to choice of diet	*"I feel like is when I'm given my own money at home I can buy green food and fruits." (G1 women)*
		"The background where we live is poor, I think we like to live healthy but they can't afford to buy healthy food." (G1 women)	Community feeding schemes	*"I think if they at the moment, we need to have like a community feeding scheme, like food parcel with veggies and fruits." (G2 men)*
	Immersed in household chores, no time for exercise	*"Sometimes it is not easy for me if I can just have two minutes of my time to exercise in my household." (G1 women)* *"I'm always busy Like cooking and cleaning you know house duties and get tired so I don't get time to exercise." (G3 women)*	Become independent	*"Start taking responsibility of your life, when you start having your own place, you start buying groceries for yourself." (G4 men)* *"Staying alone is better, less duties and more time for exercising." (G3 women)*
Social influence	***Eating healthy means sickness***	*"The majority of them [peers/community members] believe if you eat healthy stuff like veggies right, it means that you are sick with things like with HIV/AIDS or something you know so I rather not eat." (G4 men)*	Start nutrition group discussions	*"Make a group discussion with people and educate each other on nutrition." (G3 men)*
Influence by neighbourhood environment	***Junk food is all over and cheap***	*"A lot of places all you see is junk foods, every street they selling bunny chows and fat cakes." (G3 women)*	* Starting community gardens	*"In our community we do gardening, So we can provide those veg and fruit to those in need within our community." (G3 women)*

		"There are pictures of KFC all over, taxi ranks and by the road to Maponya [local shopping mall] too you just want it." (G1 women)	* Promote healthy eating through adverts	*[We need] "Adverts to promote more healthy living tips or healthy foods and less unhealthy foods like more veg not beer." (G4 men)*
		"It is difficult for me to eat healthy you find that the shops in my area are selling all the junk foods." (G1 women) *"Around me there is a Spaza that sells tempting food like the Kota." (G1 women)*	* Healthcare professionals providing awareness on junk foods * Treat unhealthy eating like a pandemic	*"Health workers can go to fast food places like Spazas and then teach people instead of having all the junk foods rather go this way to help your health." (G1 women)* *"The government must address the nation like with Covid, address with a couple of food that is unhealthy and show healthy one, do same like hand sanitizers when you go to the shop you know it is law." (G3 women)*
		"In my area I can't jog outside, there are always boys sitting at the corner saying embarrassing things about my body and their presence makes me feel uncomfortable." (G1 women)	Government building infrastructure for physical activity	*"Government must hire security officers in community parks so like training equipment are not broken and stolen by Nyaope [A local street drug, created by combining heroin, cannabis and other substances] boys. We just want to feel safe you know." (G3 women)*
	No gyms! Exercising outside is unsafe	*"I believe like to be in a physical activity I need to go to gym and things like that which is something that is not there in our area." (G1 women)*	Use space around you	"Use the parks to gym, you can play soccer, you can use the streets, you can run. And you can actually just gym inside your yard." (G2 male)
		"I want to wake up at 6 and jog but if you are a girl you can't do it at night, it is not safe." (G1 YA women) *"In my community there was this one issue where one woman, when they were busy training or exercising at the park they were raped." (G3 women)*	* Security officers in parks * Community patrol forum for protection	*"Government must hire security officers in community parks so like training equipment are not broken or stolen." (G2 men)* *"The only solution - have the community patrol forum looking after us during that time of physical exercises that we will be having." (G4 men)*

Chapter 5: Paper 3

Gudani Mukoma, Edna N Bosire, Polly Hardy-Johnson, Mary Barker, Shane A Norris. *'We were not allowed to gather even for Christmas.'* Impact of COVID-19 on South African Young People: Exploring Messaging and Support, Global Public Health (Revisions submitted: 03 March 2023).

5.1 Introduction

The unprecedented Coronavirus (SARS-CoV-2) infection was declared a pandemic on March 11, 2020 by the WHO (266, 267), causing widespread disruptions of public health systems and affecting global economies (268). The first case in Africa was reported in Nigeria on 28 February 2020 (269). The National Institute for Communicable Diseases (NICD) confirmed the first case of COVID-19 in South Africa (SA) on March 5, 2020 and since then it holds the record of the highest number of cases in Africa (223). The SA government declared a national state of disaster on 15 March 2020 followed by nationwide lockdown on 27 March 2020 to avoid overwhelming the health system and control the transmission of the disease (270). This had a severe negative, and long-term impact on the economy, starting with immediate loss of economic activity (271). As a result, unemployment increased with low-skilled, less-educated workers being hit the hardest by the loss of livelihood (272).

These economic shocks including wage reductions and loss of income, compounded by quarantine, social isolation and lockdown measures led to increased levels of food insecurity (271, 272). Almost 24% of South Africans were affected by moderate to severe food insecurity in 2020, of whom almost 15% experienced severe food insecurity (273). In-addition, these COVID-19-related disruptions and to education programs may have lifelong implications for young people since adolescence is a critical developmental phase (274-277). Government-offered interventions such as the COVID-19 Social Relief Grant and online learning programs (278-280) were not sufficient to ease the socio-economic disruptions.

Previous research, including longitudinal data, has demonstrated that COVID-19 prevention measures affected young people's mental health including increased levels of anxiety and depression (281, 282). Studies conducted in SA indicated that mental illness rose during the pandemic, disproportionately affecting the poor through mechanisms linked to structural

inequality, unemployment and lack of access to quality health care and other services (283, 284).

While studies on the impact of COVID-19 in SA have been reported, they have not clearly reflected on the in-depth analysis of the impact of events across time and how impacts evolved as the COVID-19 pandemic progressed. This paper reports findings from longitudinal qualitative research with young people for 8 months of the pandemic with the aim of exploring young people's knowledge and perceptions of COVID-19 and how the pandemic affected their lives across different periods.

5.2 Methods

5.2.1 ***Design and Setting***

This longitudinal qualitative study was conducted at the SA Medical Research Council (SAMRC)/Wits Developmental Pathways for Health Research Unit (DPHRU) at the Chris Hani Baragwanath Academic Hospital (CHBAH) in Soweto from November 2020 to June 2021. Soweto is one of the most well-known historically disadvantaged townships in SA distinguished by its diverse communities, socioeconomic status and cultures (187). However, while there is economic diversity in Soweto, poverty indicators such as unemployment and food insecurity are still present (241), alongside limited access to health services, especially for young people (242). We used focus group discussions (FGDs) for data collection. FGDs were chosen to enable interaction, socialization and knowledge sharing – at a time when many people were isolated. Longitudinal FGD design facilitated a better understanding of a range of perspectives of young people's experiences of COVID-19 (285, 286).

We draw from the health belief model (287, 288) to understand young people's behaviour's as COVID-19 unfolded in South Africa. Health Belief Model (HBM) posits that positive factors increase pro-health behaviours while negative factors decrease or inhibit them. Thus, for an individual to adopt a positive health behaviour and/or avoid risks for diseases, he/she must: (1) believe to be susceptible to the disease; (2) believe that the disease will negatively impact, at least moderately, their life; (3) believe that adopting certain behaviours is indeed beneficial to reduce their susceptibility or, if they already have it, its severity (287-289).

5.2.2 *Participants and recruitment*

We recruited a convenience sample of thirty self-identified Black young people (n=15 men; n=15 women) aged between 16 and 21 years from Soweto households. Research assistants (RAs) entered households in Soweto communities close to the DPHRU to recruit eligible participants using information letters outlining the purpose of the study and providing contact information for the research team. Recruitment began when movement restrictions were relaxed for some activities including health-related research. RAs observed all COVID-19 safety measures when visiting households. RAs collated the information on potential participants who were then called by phone to schedule appointments for discussions. Four groups were formed from those who to agreed take part. The groups were homogenous by gender and age: two with young men (aged 16-17 years and 18-21 years) and two with young women (aged 16-17 years and 18–21 years). The purpose of this was to capture the differences in views among young people.

5.2.3 *Data collection*

Each FGD was composed of 7-8 participants. Two trained and experienced multilingual, qualitative researchers (a man and a woman), facilitated 24 virtual focus group discussions (FGDs), which were conducted in 6 phases – each phase was composed of four FGDs stratified as follows: Group 1 was with women (18-21 years), Group 2 with men (18-21 years), Group 3 with women (16-17 years) and Group 4 with men (16-17 years). FGDs were facilitated in English with the option for participants to use vernacular languages. FGDs in the six phases were facilitated using a semi-structured discussion guide (Appendix H) – with the moderator exploring participants' views and responses to the COVID-19 pandemic between November 2020 and June 2021. All six FGD phases were conducted virtually through Zoom. A R150 airtime recharge voucher was provided to all participants the day before each FGD to assist with internet connection costs. FGDs lasted 45-90 minutes. All FGDs were audio-recorded on a digital recorder, with participants' permission. One researcher observed the FGDs, taking detailed field notes about group dynamics and participant reactions. Audio recordings were transcribed verbatim and translated into English, where necessary. All participants gave written informed assent or consent, depending on their age, prior to participating in the study. A parent/caregiver consent was also sought for all participants under the age of 18 years.

5.2.4 *Data analysis*

Data were thematically analysed (252, 253) and organized using qualitative analysis software MAXQDA 2020 (version 20.4.2). All transcripts from the six phases, as well as field notes were uploaded into MAXQDA. Codes were developed both inductively (from the data itself) and deductively (based on research questions and earlier discussions from the field notes). Initially, field notes, early discussions and deliberations on the FGDs provided a starting point for the development and definitions of an initial codebook. GM and ENB developed the codebook, which was reviewed by other researchers. The codebook was discussed including code definitions, then reviewed and revised codes based on mutual agreement amongst researchers. This codebook was used for coding – as codes were applied to relevant text in the transcripts. GM and ENB coded separately while discussing and iterating on any emergent new code, which was discussed and added to the codebook. After all transcripts were coded, ENB and GM met to discuss and resolve any discrepancies in coding. Thereafter, analysis was performed where key themes and sub-themes were identified, grouped, and consolidated into various categories. The themes are also presented in a meaningful structure and tabulated in tables (see Tables 8 and 9). Key themes and sub-themes are presented in the results section, using excerpts from the transcripts.

5.2.5 *Ethical considerations*

Written informed consent was obtained from the study participants after researchers read the information sheet aloud and explained the purpose of the study at the beginning of the first FGD. The Human Research Ethics Committee (HREC) of the Witwatersrand University granted ethical approval - ethics number M170663.

5.3 Results

In this section, four key themes identified are presented under the following headings: 1. Knowledge about COVID-19 and Sources of Information; 2. COVID-19 perceptions and Conspiracies; 3. Impacts of COVID-19; 4. Perceptions of COVID-19 vaccines.

Knowledge about COVID-19 and Sources of Information.

Although participants across all phases demonstrated a general understanding of COVID-19, participants in phases 4 to 6 demonstrated a more specific understanding of COVID-19, including how it spreads, dangers of COVID-19 infection and prevention measures that were being implemented by the South African government than they did in phases 1 and 2. To begin with, an increase in COVID-19 knowledge was largely linked to the increased awareness in the general public including amongst their teachers and parents; '*My English teacher told us that even if a person in class tests positive the only way they can infect us is if you don't have your mask on and you don't sanitize and stay in the same room that is not ventilated for more than 15 minutes.' (Phase 3\SATEC-19_FGD_ women 18-21 yrs).* In addition, we observed that as we progressed with discussions through the various phases of (from Phase 1-6), there were more discussions and debates around COVID-19 and participants were providing their subjective experiences in relation to their families and peers. This enhanced more learning and understanding of COVID-19. In addition, participants engaged in questions and clarifications around how COVID-19 was unfolding in SA, and some commented that the FGDs were helpful as they helped them interact with their peers.

Secondly, participants understood and discussed various COVID-19 preventive measures such as wearing of masks, hand washing and sanitization, social distancing and stricter lockdown measures. However, we noted that social distancing, curfews, hand washing and wearing of masks were commonly discussed between phase 1-4. This was in line with the measures that were being implemented by the SA government during the Level 5 lockdown where there were restricted movements and people were required to observe all the COVID-19 preventive measures (290, 291). In phase 5-6, participants revealed that life was moving to 'normal' as businesses, schools and other activities had resumed. As such, most of the preventive measures were not being observed in the community: '*We are now in Alert level 1 and I can see a lot of things have gone back to normal like businesses and schools. What I've noticed is people are starting to forget about this pandemic that we are facing as a country, people are not social distancing or even wearing their masks.' (Phase 5\SATEC-19_FGD_ men 18-21 yrs).* Such reluctance to adhere to preventive measures were also influenced by vaccine roll-out in the country – as participants reported that they felt more safer with vaccines being administered when compared to earlier phases.

We also noted that participants in phases 2 and 3 demonstrated a clearer understanding of the nature and severity of the COVID-19 infection; *'So, they did explain that the second wave means that this second strain has become stronger. (Phase 3\SATEC-19_FGD_ men 18-21 yrs).* Such sentiments were reported when SA was experiencing a deadlier newer variant 501Y-Vs (Beta variant) when compared to the one experienced in Wave 1. In addition, at this time, government was constantly reporting or updating the public on the increasing numbers of new infections and participants seemed to understand the severity of the new variant as exemplified by one discussant; *'I know we are now facing a deadly variant. The government has constantly updated us and told us how we should prevent ourselves from getting infections' (Phase 3\SATEC-19_FGD_ women_16-17 yrs)*. In addition, our longitudinal approach identified that whenever there were spikes in COVID-19 in SA, participants believed they were more at risk of infections, leading to increased adherence to preventive measures. In other words, risk perceptions positively influenced adoption of preventive behaviours; '*I've heard that we are actually in the third wave, and it is actually bad because like already I know two people that it has already taken [died of]. So, I'm following the precautions available like sanitation, masks everything. (Phase 6\SATEC-19_FGD_ men_18-21 yrs).*

However, our findings show that the more knowledgeable people were about COVID-19 – including access to information and introduction of vaccines, the less scared they were about COVID-19 infection as described above. This was commonly discussed in phases 5-6. These findings demonstrate that there is a need for the government to develop positive behaviours change interventions whenever there are new variants (as participants are keen to listen) as well as new interventions (such as vaccines) – as participants may assume that they are no longer at risk of infections. Participants reported various channels that they used to get COVID-19 related information. Those in phases 1 to 4 largely relied on parents, teachers, school, social media (WhatsApp, Facebook) and TV for updates. This can be attributed to the fact that in these earlier phases, there was a complete shutdown of various amenities including schools and young people spent time at home with parents; some engaged with teachers through online platforms. This is in contrary to the sentiments we got in phases 5-6 where participants mentioned that in addition to the sources of information reported in their earlier phases, they

now relied more on internet (google) and newspapers as sources of information; '*At the start I didn't know much so I used to Google about it. Then after third term that is when my mom told me we might be experiencing the second wave of the Corona virus. So, I did Google about how to prevent it.' (Phase 5\SATEC-19_FGD_Women 16-17 yrs)*. While there were various channels of accessing information, a majority trusted information provided by parents, teachers, and school more than they did information from the internet. Participants noted that sometimes, information from the internet and social media was exaggerated, and this formed the basis for COVID-19 conspiracies and mistrust. It was also reported that information provided by local TV and radio was not sufficient to enable people to make decisions such as whether or not they should be vaccinated; *'With me I learnt a few things about COVID-19 by watching the TV and by Googling. Because sometimes the TV doesn't give much information.' (Phase 2\SATEC-19_FGD_Women 16-17 yrs).*

Interestingly, despite receiving frequent updates on new deadlier variants of COVID-19 (Table 8), participants in phases 3, 5, and 6 reported losing interest in COVID-19 news. They argued that they were tired of listening to such news and wanted to live normal lives: '*No I've stopped [watching news] because I don't want to know anything about it because to me it feels like this thing is just a little thing. So, I don't follow news anymore.' (Phase 3\SATEC-19_FGD_ women_18-21 yrs).* Another participant said: '*Honestly the interest is gone. People no longer want to hear anything about the virus.' (Phase 5\SATEC-19_FGD_ men_18-21 yrs).* Disinterest in COVID-19 among young people during wave 2 (Beta variant) may have been attributable to their perception that they were subjected to conflicting information from multiple sources. In addition, participants revealed that there were limited updates from the government during this time in relation to COVID-19 situation- and this made some people think COVID-19 was getting over. Moreover, during phase 4, the first consignment of the AstraZeneca vaccine doses had arrived in the country which caught people's attention. As such, people were more interested to hear news around vaccines including its access and who were prioritized to be vaccinated. The government should ensure constant communication to the public, especially ensuring people have access to reliable information. This should be key especially when new interventions are being introduced so as to curb any misinterpretations such as low risk perceptions.

COVID-19 perceptions and Conspiracies.

Participant's perceptions of COVID-19 changed over time. In the earlier phases (phase 1-2), a majority of participants revealed that they were not worried about COVID-19. This was said to be common amongst their peers; '*People my age don't care. They are not wearing masks, not social distancing, not sanitizing. I think they will care if they lose someone close. They don't think it's real.' (Phase 1\Covid 19 FGD _men 18-21 yrs)*. Such sentiments were largely due to the novelty of the virus – where many people lacked information about COVID-19 and its severity. However, a few participants in these earlier phases revealed that they feared COVID-19 infections, and closely followed COVID-19 news updates to get more information about the pandemic. While there were confusions and limited access to information during these earlier phases, those who demonstrated fear to infections revealed that they had witnessed on TV or listened to radio how people were dying in other countries.

Participants particularly in phases 1 to 4 discussed the various conspiracies related to COVID-19. During this time, young people reported accessing information from various sources as discussed above – some of which was unreliable or exaggerated. For example, young people discussed that COVID-19 was unreal or did not exist or was a disease manufactured in the laboratories; '*I feel that this Covid 19 doesn't even exist, it is just a disease the scientists brought into this world, just to decrease our population.' (Phase 3\SATEC-19_FGD_ women_16-17 yrs)* Another theory was associated with participants likening COVID-19 to flu or the common cold many downplaying its seriousness; *'I think we are talking about the flu which kills people…' (Phase 2\SATEC-19_FGD_ women_18-21 yrs); 'So corona virus has similar symptoms like a flu, that means you can't identify if you are having a flu or you are having a corona virus.' (Phase 1\SATEC-19_FGD_ men_18-21 yrs)* Others suggested that COVID-19 was a 'scare' and that news related to COVID-19 infections and deaths was intended just to scare: '*They [young people] don't follow COVID-19 rules because they think Corona virus is a pandemic scare.' (Phase 2\SATEC-19_FGD_ women_18-21 yrs).*While more women than men discussed the various conspiracies and rumours that they heard in their communities; *'I was scared because there were rumours going around that COVID-19 makes young girls infertile and is aimed for population control,' (Phase 5\SATEC-19_FGD_ women 16-17 yrs)*, our analysis show more young men in all FGDs demonstrating mistrust of COVID-19. In other words, young

men believed in some of the conspiracies around COVID-19 and believed COVID-19 was not real.

As a result, many young men – who demonstrated disbelief and mistrust of COVID-19 messaging also reported that they did not adhere to COVID-19 preventive measures; *'I can't believe what I am told, I'm very unsure. That's why I don't wear masks' (Phase 2\SATEC-19_FGD_ men 18-21 yrs)*. For the women who mentioned that they were non-adherent to COVID-19 preventive measures, we found that difficulty breathing and the discomfort of wearing masks for longer times; *'People are not following the preventive measures. Let's use the mask as an example, its irritating to the point where I can't even breathe normally.' (Phase 2\SATEC-19_FGD_ women_16-17 yrs)* and stigma from peers (especially from young boys) around wearing masks influenced them to become non-adherent: *'My peers do not care about COVID-19. When they see other people wearing mask, like old people, they will just laugh and gossip.' (Phase 2\SATEC-19_FGD women 16-17 yrs)* These findings align with other studies conducted in other African countries which shows young boys being influenced by conspiracy theories and perceiving themselves to be at lower risk of infections (292). As such, there is need to develop preventive messages to counter conspiracy theories during pandemics and ensure such messaging could be tailor made to address men and women concerns. This may be one way to promote adherence to public health preventive measures.

Impacts of COVID-19.

Household financial insecurity was the most discussed impact of COVID-19 by both young men and women, and particularly in the earlier phases (1-3). Participants had witnessed job loss within their households and the community. They reflected on how tough things had become, worsened by closing of businesses during lockdowns. Family members relying on informal economies were unable to work or look for jobs. They watched their families struggle to afford basic needs such as food and housing. As a result, many households, including children, were struggling to survive; *'My mother lost her job, and they didn't get payment at work. My brother didn't go to school, and he struggled to understand' (Phase 1\Covid 19 FGD men_ 18-21 yrs); 'Our economy is collapsing. This pandemic is just making our situation worse. It's been a real struggle to get food.' (Phase 1\SATEC-19_FGD_ men_16-17 yrs)*. Indeed, during these earlier phases, the South Africa government had put strict measures - Alert level 5 (293-296) where

movement was restricted, and most businesses were closed down. In fact, the Coronavirus Rapid Mobile (CRAM) survey conducted just after we conducted phase 3 of our interviews reported that hunger had worsened despite welfare payments to fight the impact of COVID-19 (297-299).

Some participants were worried about inability to access food in their neighbourhoods. Others revealed that there was reduced food stocked in local stores or grocery shops, or that food was now expensive to buy. Although the South African government moved swiftly to cushion its citizens especially the elderly and marginalized with social grants and food parcels, some participants felt the support was not sufficient to take care of entire families especially in larger households.

The second most discussed impact was schooling – commonly between phases 1-3. Participants talked about difficulties studying from home following school closures, mostly because they lacked necessary infrastructure; '*Many people didn't have access to data and the [schools] don't supply proper equipment for digital learning.' (Phase 1\Covid 19 FGD_ women_18-21 yrs)* Others mentioned that studying from home or online was challenging because '*teachers did not explain the way I would like them to explain because, unlike learning face-to-face at school, you get to ask them different kind of questions in order for you to understand.' (Phase 1\SATEC-19 FGD_ women_16-17 yrs)* Despite this, participants noted that not all learners experienced these challenges evenly. For example, learners who could afford private coaching at home were perceived to have managed the situation better than those from poorer backgrounds: '*Those who come from poor backgrounds won't cope, they won't get good mark because now it is not their thing. For those that can afford they could hire a private tutor maybe they will get help from there.' (Phase 3\SATEC-19_FGD_ men_18-21 yrs)*

As a result, most participants in these earlier phases reported that they were worried about scoring poor marks, inability to complete the syllabus or being asked to repeat classes:
'Well number one of my worries was my academic yes, in terms of not going to school, like the others said, repeating the same grade next year, yeah that was frustrating honestly.' (Phase 1\SATEC-19 FGD_women_16-17 yrs). Participants also noted challenges when schools reopened: '*When we went back the first time it was really scary because the teachers were putting so much pressure on us to always sanitize, and always have our face shields on and it*

was hard the social distancing.' (Phase 2\SATEC-19_FGD_ women_16-17 yrs) In addition catching up the lost lessons during lockdown was another source of concern amongst discussants: '*Okay, right now things are a bit shaky because as grade 12, we will have more pressure because we have to catch up last year's work and all the work for grade 12'. (Phase 3\SATEC-19_FGD_Group 3 women_16-17 yrs)*

Inability to socialize with friends or peers was also discussed as a negative impact of COVID-19. For example, young people were particularly upset at not being able to associate during Christmas festivities: '*Okay, my festivities were not the ones that I'm used like the ones before everything has changed completely. We were not allowed to gather even for Christmas.' (Phase 3\SATEC-19_FGD_ women_16-17 yrs)* Another discussant in a different FGD said: *'Yes because the president said we can't light up fireworks and we should light candles and pray so that 2021 could be a better year.' (Phase 3\SATEC-19_FGD_ women 18-21 yrs).* Despite this, one participant in phase 3 reported how he was amazed by the fact that people were able to follow government's directives; '*I was amazed. People listened and the streets were quiet. Everyone was inside their house everything worked out.' (Phase 3\SATEC-19_FGD_ men 18-21 yrs)*. However, he noted that Christmas wasn't as joyful.

However, some participants reported that they experienced positive impacts of COVID-19 such as: *'It brought us (300) much closer so that we could understand each other….'. (Phase 1\Covid 19 FGD group 2 men_ phase 1 18-21 yrs); 'Parents are now spending time with us more because, before COVID-19, they were always working, sometimes not coming home.' (Phase 1\SATEC-19_FGD_Group 4 men_16-17 yrs).* Spending time with family and relatives within the home was also said to help young people cope with uncertainties of the pandemic. Others mentioned that they had enough time to sleep, relax or play which helped them to relax*: 'My mom made sure I don't go out. I was sitting at home playing video games which helped me a lot.' (Phase 1\Covid 19 FGD men 18-21 years); 'I spent my time cleaning, watching TV and sleeping.' (Phase 1\Covid 19 FGD women 18-21 years).* All these sentiments reflect the measures put in place to restrict movements during Wave 1 of COVID-19 in SA, and families had to spend time at home.

Importantly, young people felt that COVID-19 had a negative impact on their mental health and psychological well-being. Although we did not conduct any mental health assessments,

many participants reported that they were worried about failing exams or scoring poor marks, something that seemed to be a major concern amongst all school going young people across all groups. In addition, participants demonstrated psychological distress – which was associated with constant fear of infection, fear of their parents dying or getting infected; '*I was scared for my granny and mother. My mother's friends contracted the virus, and I was scared for me and my little brother.' (Phase 1\Covid 19 FGD men_ 18-21 yrs).* Others were able to articulate specific effects on mental health: *'What bothered young people is like depression, and other psychological factors that led to the depression. The pandemic made them lose hope. A lot of my peers are at home, and they tried applying for jobs and some didn't get to university. (Phase 1\Covid 19 FGD men_ 18-21 yrs).* Indeed, in the earlier phases of the pandemic, people across the globe experienced distress as they did not know how the pandemic would unfold. The distress was heightened by increasing numbers of infections and deaths.

However, during the later phases of our study (Phase 5-6), participants seemed calmer and more relaxed during FGD discussions. Some reported that they were less anxious or worried about COVID-19 when compared to earlier discussions: *'I think that people are now less worried about this whole Corona virus. I am less anxious and now accustomed to COVID-19.' (Phase 5\SATEC-19_FGC_Men 16-17 yrs).* Such sentiments may have been influenced by the fact that there was clearer information on preventive measures, vaccines had started being administered, number of infections and deaths were dropping and that things were getting back to normal- including children going to school and people going back to their jobs and businesses. Yet, as discussed above, such relaxation or getting accustomed to COVID seemed to also influence non-adherence to COVID-19 preventive measures in the later phases. Our findings show that this should be a critical period for more sensitization on preventive measures and encouraging people the importance of adherence.

Perceptions of COVID-19 vaccines.

Issues with vaccines were commonly discussed in phases 3-6. A more detailed understanding of vaccines including the types of vaccines and the types that were being used in SA emerged in phases 5 and 6, however: '*The vaccine that was used was Johnson & Johnson. It was given*

to our medical workers. (Phase 5\SATEC-19_FGD_ men_18-21 yrs). Although vaccination had started, some participants noted that there was no proper messaging to support their uptake: '*I haven't had a person telling me about he or she has taken the vaccine. Even my granny doesn't want to take the vaccine. (Phase 6\SATEC-19_FGD_ women_18-21 yrs).* In this vein, one participant said that; *'If more information was given to us and the research is done right that is when the people will change their mind. But for now, people are not ready to take the vaccine.' (Phase 5\SATEC-19_FGD_ men 18-21 yrs)*

This lack of clarity and information around vaccines influenced participants' feelings about vaccines. Expression of mixed feelings were especially common in phases 3, 4 and 5 and mostly common among young men; many demonstrated distrust in vaccines: '*If ever it comes to a push where we all have to get vaccinated, then I think I would rather die than be vaccinated. (Phase 5\SATEC-19_FGD_men_18-21 yrs); 'To be honest I don't actually follow up on the whole vaccination thing I just see what I see and for me anything that has vaccine inside I wouldn't take it.' (Phase 5\SATEC-19_FGD_ men_18-21 yrs).*

Towards the last phase of discussions (phases 5 and 6), participants seemed more knowledgeable about vaccines and demonstrated willingness to be vaccinated. They also reported that some of their family members had been vaccinated with no ill-effects; '*What made me think positive about the vaccine is that I get to see that it does not bring any negative symptoms as my aunt was also vaccinated. Also, a lot of people have been vaccinated now.' (Phase 5\SATEC-19_FGD_ women_16-17 yrs).*

5.4 Discussion

We used a longitudinal qualitative design to explore young people's knowledge and perceptions of COVID-19, and how the pandemic affected all aspects of their lives. Our findings show that knowledge about COVID-19 increased across the phases, and this was in part due to increase in access to information including discussions amongst participants during FGDs. Knowledge and understanding of COVID-19, as well as access to trustworthy sources of information was key in influencing how young people responded to COVID-19 preventive measures. Yet, we learnt that although many young people had a general understanding of COVID-19, this did not translate to behaviour change such as wearing masks. This was, in part, due to other compounding factors such as conspiracies around COVID-19,

misinformation, rumours, and distrust on information particularly from the internet. Participants felt that at the start of the pandemic, information reported on social media was exaggerated, resulting in mistrust and conspiracies. Participants trusted information relayed through TV and Radio although felt that this information was inadequate to support young people in engaging with preventive measures like vaccinations.

Mistrust in COVID-19 information was also worsened by conspiracy theories which the young people felt were heightened by a sense of vulnerability triggered by the sustained threat to physical, mental/psychological, and financial well-being. Prior to the COVID-19 pandemic, there have been other examples of conspiracy beliefs greatly influenced denial and mistrust of biomedical explanation and treatment of highly stigmatized diseases such as HIV/AIDS (301). Notably, conspiracy beliefs have also been found to have a widespread history embedded in culture, politics and religion – including instances where political elites in South Africa have jeopardized timely access to antiretroviral therapy (ART) medications, thereby increasing HIV infections and deaths especially amongst children (302, 303).

Studies conducted in many countries in Africa have also shown that conspiracy theories especially when COVID-19 was declared a pandemic, influenced people's uptake of preventive measures (304-307). Our data revealed that whenever there were spikes of increased infection, young people believed that they (including their parents/caregivers and peers) were at risk of infection, which lead to increased adherence to preventive measures. However, this was only sustained for a brief period, and many went back to less adherent behaviours whenever risk perceptions were low. These findings suggest that strong fear appeals result in the greatest behavioural change only when people feel efficacious (308, 309). This supports the HBM hypothesis that health-related action dependent upon the simultaneous occurrence of a health concern, vulnerability and the belief that following a particular health recommendation would be beneficial in reducing the perceived threat (287, 289). In contrast, strong fear appeals coupled with low-efficacy messages result in the most defensive responses or avoidance coping strategies, both of which may contribute to a lack of adherence to preventative measures (310). Young people held the belief that their limited knowledge, mistrust, and conspiracy theories strongly influenced their level of engagement with protective measures. However, by phases 5 and 6 of data collection, participants

demonstrated more knowledge and ability to access trustworthy sources of information (e.g., TV and newspapers). This enabled them to make informed decisions about adopting preventive measures such as vaccinations.

We also found that the more knowledgeable young people were about COVID-19, the less scared they were about being at risk of infection. In addition, minimal risk perception was linked to introduction of vaccines – where young people perceived that vaccines would reduce infections and deaths. While COVID-19 vaccines have reversed the trend of infections and deaths across the globe (311-313), it is important to ensure continuous sensitization, education and creating updates especially amongst young people to increase uptake of preventive measures. We also found that young people's focus and behaviour shifted from being focused on their own wellbeing to being more considerate of others. Many talked about being worried about the risk of their parents/friends/neighbours becoming infected with COVID-19 demonstrating a concern for others when confronted by disaster (314). This adds to existing findings on the ways people cooperate rather than compete in response to a crisis (315). This feeling can be used in future public health preventive measures and messaging in SA, targeting use of collective terms such as 'us' and promoting action for the common good – building on the 'Ubuntu' philosophy (316, 317).

Young people discussed the various impacts of COVID-19 such as the socio-economic implications including food insecurity and financial crisis within their households (292, 318, 319). School disruptions created greater risk of widening educational disparities between the poor and rich due to lack of support and resources for remote learning among poorer families (292). Another aspect that young people highlighted as particularly difficult was the isolation associated with preventative measures and their inability to gather or socialize with peers, especially over holidays. This influenced the psychological wellbeing of young people and those around them. Participants consistently reported feelings of anxiety and being constantly worried about uncertainty over education and their future, fear of infection as well as loss of life. Despite this, the ability of family to spend time together for longer periods and avoidance of bad companies/groups, enough time to sleep and rest and watching TV were said to be positive impacts brought about by Covid-19 lockdown measures and were key strategies that

helped young people cope during the pandemic. In the later phases of our discussions, participants were more relaxed and calmer, and some reported that they were no longer scared of COVID-19. These findings point out the importance of ensuring access to information in case of pandemics- to reduce distress and other psychological disturbances that comes with onset of new diseases. Also, it is important for the SA government to ensure rapid response to address financial and food insecurities especially amongst vulnerable households. This will cushion populations and improve their mental wellbeing amidst pandemics such as COVID-19.

Our findings show that individual behaviours and risk perceptions varied across various phases of data collection and were informed by factors such as how the pandemic unfolded, conspiracies related to COVID-19 and access to information. In addition, the socio-economic contexts and family dynamics were crucial in individual's risk perceptions. These findings highlight the gaps and opportunities that could be utilized by the government to improve disease prevention and increase adherence behaviours while designing interventions that are suitable for specific populations and ages. Thus, understanding the relative contributions of individual, community and contextual factors that influence positive behaviours change is paramount in designing interventions that suits specific groups of people (320, 321).

In conclusion, community leaders, scientists, and policy leaders need to learn from the COVID-19 experience and ensure youth preventive strategies targeting education, awareness, and economic support are in place and tailored to a local context in future emergencies. Providing reliable information that considers young people's lives and the context in which they live is important.

Table 9. *Dates of data collection phases in relation to imposition of government measures and COVID-19 waves in South Africa.*

Phase name	Time when FGDs were conducted	Level of lockdown	COVID-19 wave number	Government measures	Vaccination rolls out yes/no	Key topic of FGD
Phase 1	November 2020	- Alert level 1	Wave 2. **Newer Variant 501Y-Vs (Beta variant)** **Deadlier variant than in Wave 1** **Number of infections increasing**	**Lockdown:** Social, religious, political and other gatherings will be permitted, as long as the number of people does not exceed 50% of the normal capacity of a venue (Outdoor maximum 500, indoor max 250). **Preventive measures:** washing or sanitizing of hands, social distancing and masks, isolation, quarantine, **Schools:** social distancing, temperature screening, online learning **Funerals:** not more than 50 people (initially). This increased to 100 **Restricted social gatherings:** Night vigils not permitted, venues for exercise/recreation or sporting activities not allowed. **Curfew hours**: From 11pm to 4am **Businesses**: Non-essential businesses not allowed, restaurants and bars closed at 10pm, sale of alcohol permitted between 10am and 6pm and from Monday to Thursday, Alcohol consumption in all public spaces forbidden **Support:** Covid social relief grant **Travel restrictions:** restrictions from countries with high infection rates; travellers require COVID-19 negative text result not older than 72 hours from time of departure	- No	- Limited knowledge about COVID-19, conspiracies, prevention measures, fear/worry of infection and death

Phase 2	December 2020	- Alert level 1	Wave 2: **Newer Variant 501Y-Vs (Beta variant)** **Deadlier variant than in Wave 1** **Number of infections increasing**	**Prevention Measures**: washing or sanitizing of hands, social distancing and masks, isolation, quarantine **Funeral:** Increased from 50-100 people **Curfew hours**: From 11pm to 4am **Businesses**: Non-essential businesses not allowed, restaurants and bars closed at 10pm, sale of alcohol permitted between 10am and 6pm and from Monday to Thursday, Alcohol consumption in all public spaces forbidden **Schools:** Closed **Support:** Covid social relief grant **Gatherings: Restricted** numbers of people congregating in any one place without proper controls or protocols not allowed	- No	Conspiracies, information sources, total shutdown, fear/worry of infections, prevention measures, new variant
Phase 3	January 2021	- Alert level 3	Wave 2: **Newer Variant 501Y-Vs (Beta variant)** **Deadlier variant than in Wave 1** **Number of infections increasing**	**Prevention:** Mandatory wearing of a face masks in public spaces, social distancing, hand washing and/or sanitization **Curfew Hours: from** 9pm to 5am **Businesses:** Non-essential establishments like restaurants, bars and fitness centres closed by 8pm, all types of work outside home permitted under strict compliance to health protocols and social distancing measures **Schools:** closed until 14 February **Support:** Covid social relief grant **Alcohol:** Sale of alcohol for off-site and on-site consumption not permitted **Gatherings:** Prohibition of social gatherings; political meetings, traditional council meetings and faith-based gatherings.	-No - It was announced that the first consignment of COVID-19 vaccines will be received soon, in SA	Conspiracies, total shutdown, poor adherence to prevention measures, social relief grant, new variant, perceptions on vaccines

Phase 4	February-March 2021	- Alert level 3	Wave 2: **Newer Variant 501Y-Vs (Beta variant)** **Deadlier variant than in Wave 1** **Number of infections increasing**	**Curfew hours**: from 11pm to 4am **Prevention:** Mandatory wearing of a face masks in public spaces, social distancing, hand washing and/or sanitization **Gatherings:** Night vigils or other gatherings before or after funerals not permitted. All gatherings were limited 50 people indoors and 100 people outdoors or no more than 50 per cent capacity if the venue is small. **Businesses:** Non-essential establishments like restaurants, bars and fitness centres closed by 10pm, all types of work outside home permitted under strict compliance to health protocols and social distancing measures **Schools:** all learners returned to school 15 February, social distancing, temperature screening, online learning **Support:** Covid social relief grant **Alcohol:** Sale of alcohol for off-site consumption permitted from 10am to 6pm, from Mondays to Thursdays; on-site consumption permitted, from 10am to 10pm	- No -AstraZeneca vaccine doses arrived	- Specific knowledge of COVID-19, its spread, risks, and prevention, vaccine perceptions and rollout
Phase 5	April 2021	- Alert level 1	Wave 2: **Newer Variant 501Y-Vs (Beta variant)** **Deadlier variant than in Wave 1**	**Curfew Hours:** from 12 midnight to 4am **Gatherings**: Maximum number of people allowed at any gathering was 100 people indoors or 250 people outdoors or no more than 50 per cent capacity if the venue is small. Night vigils or other gatherings before or after funerals not permitted. **Businesses:** Non-essential establishments like restaurants, bars and fitness centres closed by	- Yes (Pfizer)	- Specific knowledge of COVID-19, less worried of infections, vaccine rollout, vaccine hesitancy

			Number of infections increasing	11pm, all types of work outside home permitted under strict compliance to health protocols and social distancing measures **Schools:** social distancing, temperature screening, online learning **Support:** Covid social relief grant **Travel Restrictions:** Only five airports were open for international travel. **Prevention:** The wearing of masks in public places mandatory **Alcohol:** Sale of alcohol permitted		
Phase 6	June 2021	- Alert level 3	Wave 3: **New Variant (B.1.617.2)** **Increased number of infections 15.7% above the WHO threshold of 5%**	**Curfew:** hours of curfew started at 10pm and end at 4am **Businesses:** Non-essential establishments like restaurants, bars and fitness centres closed by 9pm, all types of work outside home permitted under strict compliance to health protocols and social distancing measures **Schools:** social distancing, temperature screening, online learning **Support:** Covid social relief grant **Gatherings:** Limited 50 people indoors and 100 people outdoors or no more than 50 per cent capacity if the venue is small. Attendance at funerals and cremations was set at 50 people. **Alcohol:** Alcohol from retail outlets for off-site consumption was permitted between 10am and 6pm from Monday to Thursday	- Yes (Johnson and Johnson & Pfizer)	- Less worried of infections, vaccine hesitancy, living with COVID-19, schools reopening, getting back to normal

Table 10. *Key themes and sub-themes identified from the FGDs.*

Themes	Sub-theme	Phases where these themes were identified
Knowledge about COVID-19	General understanding of COVID-19, understanding of preventive measures, knowledge about infections	Phase 1,2,3,4,5,6
	More knowledgeable about COVID-19	Phase 2 & 3
	No longer scared of infections	Phases 4,5,6
Source of Information	Teachers, parents/guardians, TV, Radio, social media platforms, WhatsApp groups	Phase 1,2,3,4,5 & 6
	No longer interested in COVID-19 news, stopped following COVID-19 updates	Phase 3, 5, 6
COVID-19 Perceptions	Fear of infection (self), fear of family being infected, High-risk perception	Phase 1, 3 & 5
	Taking COVID-19 for granted non-adherent to COVID-19 measures	Phase 1, 2
	COVID-19 conspiracies: Likened COVID-19 with flu, COVID-19 perceived as a scare threat to people	Phase 1,2,3 & 4
	Reported increasing number of COVID-19 infections, increase in number of deaths	Phase 2, 3
Negative impacts of COVID-19	Job losses, food insecurity, Lifestyle changes, psychological impacts	Phase 1,2,3
	Closure of schools, home schooling challenges/ difficulties studying from home, worried about deficient performance at school, challenges returning to school	Phase 1,2,3
	Difficulties returning back to school	Phase 2 & 3
	Psychological distress: Fear of repeating classes, fear of failing in exams, stressed about elderly parents getting infected, worried about parents losing jobs	Phase 1,2,4
Positive Impacts of COVID-19	Families spending time together, avoiding unnecessary friends/negative peer pressure, more time to study, more time to relax, play video games and watch TV	Phase 1
Government Responses	Negative: Misuse of COVID-19 grants, poor leadership, police brutality	Phase 1 & 2
	Positive: Social grant, lockdown prevented more deaths, preventive measures protected people from infections	Phase 1 & 2
Vaccines	Distrust about vaccines, negative perceptions about vaccines, vaccine conspiracies, lack knowledge about vaccines	Phase 3,4 & 5
	More knowledgeable about vaccines, vaccine types, positive perceptions about vaccines	Phase 5,6
Behaviour change and moving back to stable life	Mention of consistently adhering to preventive measures: Especially whenever there were mentions of spikes in COVID-19, mention of sanitizing, wearing masks, social distancing etc. Behaviour changes also linked to high police surveillance and arresting those who do not follow laid down protocols	Phases 1,3,6
	Things getting back to normal, schools opening, people getting jobs etc.	Phase 5 & 6

Chapter 6: Paper 4

Mukoma, Gudani, Shane A. Norris, and Tinashe Chikowore. "Nutrient Patterns and Body Mass Index: A Comparative Longitudinal Analysis in Urban Black South African Adolescents and Adults." *Nutrients, 15(5), 1075; https://doi.org/10.3390/nu15051075* (Published: 21 February 2023)

6.1 Introduction

Obesity is a global epidemic (322). Obese people have a greater likelihood of dying from NCDs such diabetes and heart disease (107, 183, 184). 13% of adults (18 years and older) worldwide were obese in 2016 (11% men, 15% women) (323). Recent studies suggest that over 70% of the world's obese live in developing countries (324). South Africa now leads Sub-Saharan Africa in obesity prevalence (94, 325). Women (68%) are more likely to be overweight or obese than men (31%) (326). South African adolescents are also becoming overweight or obese (9% of boys and 27% of girls), similar to several high-income countries (326, 327). This combined prevalence has increased from age 11 to 46.5% in the 21+ age group in South African urban settings, indicating that adolescent NCD risk is rising rapidly (174). Thus, more research is needed to understand the alarming rise in obesity rates and why more women than men are affected (328).

Obesity is linked to sedentary lifestyle, poor diets, low physical activity, and insufficient sleep (329). South Africans of all ages exercise less due to economic changes and urbanization (63, 330, 331). Adults with higher SES have lower PA and a higher BMI (332, 333). The ongoing nutrition transition has led to more people eating westernized foods (meat, fats and oils, sauces, dressings, condiments, sweets, and soft drinks) (184). This diet increases weight and BMI in children and adults (325, 326). In women, obesity reduces female fertility and increases offspring obesity (334). High maternal BMI may increase birth and childhood weight due to elevated maternal glucose and insulin concentrations, which drive foetal growth and adiposity (335). Although a mother's diet affects her offspring's long-term health, little is known about a father's diet (336). However, father's lifestyle, sperm quality, and offspring health are linked (337). Male sperm count decreases when men eat a western-style diet high in sugar, fat, and processed foods (338). Furthermore, high-fat diet-induced paternal obesity damages sperm

deoxyribonucleic acid (DNA), reduces blastocyst development and implantation rates, and causes subfertility in male and female offspring for up to two generations (339). Thus, preconception risk factors for both men and women—healthy body composition, physical activity, and diet—must be addressed (340).

Research shows that poor eating habits start in the early stages of life (329). However, nutrient patterns in adolescents are rarely studied (330). Also, many of the studies done (341-343), only examined how single nutrients and foods affect obesity. Nutrient patterns across all age groups are important because humans eat different foods (224, 344-346). Several South African studies have examined nutrient patterns and adiposity in different age groups and settings (224, 345-347). Only one rural South African adolescent study found that animal-driven nutrient patterns increase BMI (224). Urban adolescents have no data on this association. In other studies of urban middle-aged South African adults, animal-driven nutrients (347), also called animal and fat-driven nutrients (345), were associated with increased BMI. The association was stronger among men than women (345). It is unknown whether there are also sex differences between boys and girls among urban adolescents. Only one study of middle-aged women showed that dietary patterns remained the same over time (346). However, data exploring this in men is not available. Also, in a publication (63) that forms part of this papers series, we found that young women of low socioeconomic status (SES) who ate a mixed diet (meat, vegetables, fruit, dairy, starch, cakes, and biscuits) and did moderate-vigorous physical activity (MVPA) had a lower BMI than women of high SES. Despite being overweight or obese, young women with low household SES had a lower risk of NCDs than those with high SES (63). Even with these results, it was unclear if eating patterns change over time, if they are the same for teens and adults, and if they relate to BMI differently for men and women. And, as most of the previous studies were cross-sectional, conducted in different age groups and settings (224, 345, 347), and only adult women were studied longitudinally (346). This paper aims is to build on our previous findings and other research (224, 348, 349) in South Africa by using nutrient pattern analysis to compare the unique eating patterns of adolescents and adults and assess their longitudinal (24-month period) effects on BMI.

6.2 Materials and Methods

6.2.1 *Study Population and Design*

Our study was conducted at the South African Medical Research Council (SAMRC)/Wits Developmental Pathways for Health Research Unit (DPHRU) at Chris Hani Baragwanath Academic Hospital (CHBAH) in Soweto. CHBAH is one of the largest hospitals worldwide and a public tertiary care institution that serves the low-income community of greater Soweto in southwestern Johannesburg, South Africa. The peri-urban neighbourhood of Soweto is well known for its established communities, as well as the socioeconomic and cultural diversity that can be found there. We adopted a longitudinal study design. The following were the selection criteria for the participants who were part of the study: (i) adolescent boys (*n* = 125) and girls (*n* = 125) aged 13–17 years, all of whom needed to be accompanied by their parent/caregiver and who resided in Soweto; (ii) young adult males (*n* = 125) and females (*n* = 125) aged 27 years old; and (iii) middle-aged men (*n* = 125) and women (*n* = 125) aged 45^{+} years. A random sampling of households in Soweto was conducted to recruit 250 adolescent participants. In addition, the purposeful selection of 250 young adults who participated in the "Birth to Twenty" cohort study and 250 middle-aged adults from the "Determinants for Type 2 Diabetes Mellitus (T2D)" study was used to obtain 500 adult participants. In total, 750 self-identified black South Africans agreed to take part in the study after being recruited. Before taking part in the study, each participant first provided his or her informed consent in written form. The Human Research Ethics Committee (HREC) of Witwatersrand University, with ethics numbers M170663 and M160604, granted ethical approval (Figure 17).

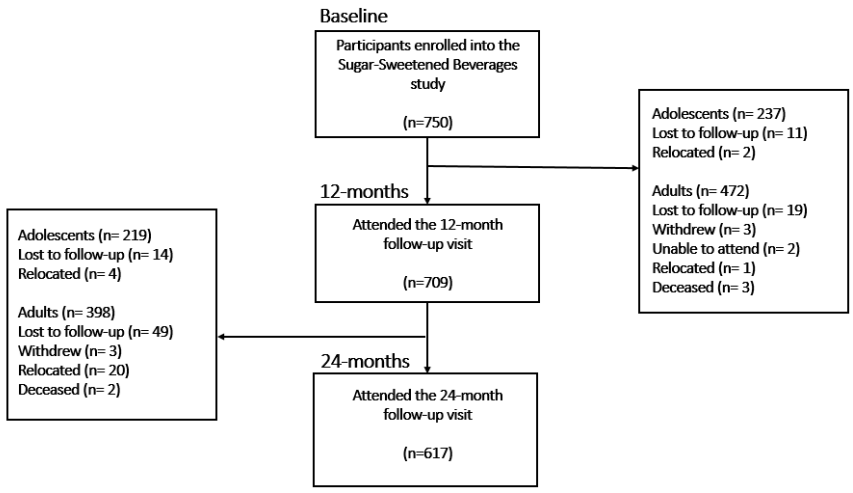


Figure 17: *Diagrammatic representation of the flow of participants in the study.*

Following the recruitment and enrolment of adolescents and adults into the study, all data were collected at the DPHRU site using the same methodology. The gathering of baseline data began in May 2017. Follow-up visits were undertaken at DPHRU after 12 and 24 months, respectively.

6.2.2 *Dietary Intake Assessment*

Dietary intake was estimated using a seven-day quantitative food frequency questionnaire (QFFQ) with 214 commonly eaten foods taken from analyses of eleven dietary surveys done in rural and urban South Africa since 1983 (122, 194). Furthermore, this tool has also been piloted and utilized extensively in Soweto as described elsewhere (28, 192, 193). To complete the QFFQ, trained research assistants used high-quality photographs of food items to trigger participants' memories of all foods and beverages consumed during the previous seven days. The participants were asked to arrange the cards into three piles: foods eaten in the last seven days, foods eaten occasionally, or foods never consumed, and this was recorded. The QFFQ was then administered and took approximately 40-50 minutes to complete. In the case of food items consumed in the past seven days, additional data on the frequency and quantity of consumption was recorded. Portion sizes were estimated using a combination of high-quality two-dimensional drawings of foods, household utensils and three-dimensional food models, which have been described and validated by Steyn et al., (194). Estimated portion sizes were converted to grams to allow for the calculation of the participant's average intake over the previous seven days. The QFFQ was captured and managed online using REDCap electronic data capture tools hosted at The University of the Witwatersrand (195). Nutrient composition (energy and macronutrients) was calculated from the conversion of single food item intakes by the SAMRC using the South African Food Composition Tables. Over and under-reporting of dietary intake was corrected by removing participants with total energy intake <3000 and >30 000kJ as described by Vorster et al. (350).

6.2.3 *Demographic questionnaires*

The Demographic and Health Surveys household questionnaire (available at: www.measuredhs.com ; accessed on 1 May 2017), which has been extensively utilized in this setting, was used to collect participant socio-demographic variables (351, 352). To assess the

household socio-economic status (SES), an asset index scored each participant according to the number of assets they possessed out of a possible 12 (electricity, radio, television, refrigerator, mobile phone, personal computer, bicycle, motorcycle/scooter, car, agricultural land, farm animals) was utilized.

6.2.4 Anthropometry

Height (in mm) was measured using a stadiometer (Holtain, UK) and converted to meters (m). Weight was measured to the nearest 0.1 kg using a portable electronic bathroom scale (Seca Gmbh & Co. KG, Hamburg, Germany). All participants were measured wearing light clothing and without shoes. BMI was calculated as weight in kilograms (kg) divided by height $(m)^2$.

6.2.5 Data analysis

The statistical analysis was performed using Stata SE version 17 and the statistical package for social scientists (SPSS) version 26. Normality tests for the continuous variables were performed using Q-Q plots. Descriptive statistics were used to describe the macronutrient intakes for adolescent and adult study participants per day. Twenty-five nutrients were used to derive nutrient patterns via principal component analysis (PCA) as described by Pisa et al. (224). Additionally, from the 25 nutrients, total protein was split into animal protein and plant protein; total carbohydrates were divided into total sugar, starch, and total dietary fibre. Total fat was categorized into saturated fat, monounsaturated fat, and polyunsaturated fat (344). The total dietary fibre comprised of soluble and insoluble dietary fibre. To remove bias due to variance due to the different measures of scale used to quantify the nutrients, we log-transformed the nutrient intake variables from the QFFQ (344). The nutrient density method was used to adjust the total energy intake (349). PCA was performed with the variance based on the correlation matrix and varimax rotation. We used the scree plot (Figure 2) to determine the number of PCs to retain (Figures 2 and 3), which we indicated as the nutrient patterns. The nutrients with loadings greater than ±0.47 on the PCs were used to name the nutrient patterns (344). The total variances explained by the retained PCs were also evaluated to determine the relevance of the extracted PCs. The Kaiser–Meyer–Olkin measure of sampling adequacy of 0.911 and Bartlett's test of sphericity, which was significant at $p < 0.001$, indicated that the PCA was a suitable data reduction approach for the nutrient data in this study.

Generalized estimating equations (GEE) regression models were computed separately for adults and adolescents to assess the association between BMI as the dependent variable. In contrast, the nutrient patterns, household SES, sex, age, estimated intake and estimated energy requirements (EI/EER) ratio, an indicator of the plausibility of dietary energy intake reporting, and GEE index were used as predictors. The EI/EER ratio (353, 354) was determined using the following IOM energy expenditure equations.

Girls (9-18 years); EER = 88.5 – (61.9 × age [y]) + PA × (26.7 × weight (kg) + 903 × height [m]) + 25 kcal).
Boys (9-18 years); EER = 135.3 – (30.8 × age [y]) + PA × (10.0 × weight (kg) + 934 × height [m]) + 25 kcal).
Men (19 years and older); EER = 662 – (9.53 × age [y]) + PA × (15.91 × weight (kg) + 539.6 × height [m]).
Women (19 years and older); EER = 354 – (6.91 × age [y]) + PA × (9.36 × weight (kg) + 726 × height [m]).
To categorize plausible reporters (0.7–1.42), under-reporters (<0.7), and over-reporters (>1.42), the EI/EER ratio was used (355).

6.3 Results

6.3.1 *Descriptive characteristics of the study population*

The median BMI level was 20.1 (18.2; 22.8) kg/m2 for adolescents and 26.6 (22.2; 32.7) kg/m2 for adults, respectively. Adult women's median BMI of 29.1 (23.7; 36.1) kg/m2 signified that a considerable proportion of the women were overweight. Overall, adolescent boys had the highest total energy intake 11305 (8709; 14153) KJ, consumed higher amounts of plant protein 35.9 (27.6; 48.3), carbohydrates 366.0 (282.4; 436.7) g/day than other groups. Boys and girls differed significantly ($p<0.05$) in terms of BMI, height, fat, carbohydrate, or EI/EER ratio. Weight, height, BMI, total energy, total protein, total fat, saturated fat, mono and poly unsaturated fat, and added sugar were significantly different between men and women ($p>0.05$). With that said, adolescent girls had higher intakes of total fat, 100.8 (73.9; 144.6) g/day, while adults had higher intakes of animal protein, 34.6 (24.5; 48.5) g/d compared to other groups, as indicated in (Table 10).

Table 11. *Descriptive statistics of macronutrient intakes for adolescent and adult participants.*

	Adolescents				Adults			
	Median (IQR)			*p*-Value [a] (M vs. F)	Median (IQR)			*p*-Value [a] (M vs. F)
	Total (*n* = 250)	Male (*n* = 125)	Female (*n* = 125)		Total (*n* = 500)	Male (*n* = 250)	Female (*n* = 250)	
Age (year)	14 (13; 15)	14 (14; 15)	14 (13; 15)	0.222	27 (27; 52)	35 (27; 55)	27 (27; 50)	0.053
Weight (kg)	52.6 (46.6; 59.8)	51.9 (44.6; 58.4)	53 (48; 60.6)	**0.012**	72.5 (60.5; 84.8)	70.5 (59.4; 81.2)	74.7 (62.8; 74.7)	**0.002**
Height (m)	1.60 (1.54; 1.66)	1.63 (1.55; 1.69)	1.57 (1.53–1.62)	**<0.001**	1.64 (1.58; 1.71)	1.68 (1.62; 1.73)	1.61 (1.56; 1.66)	**<0.001**
BMI (kg/m^2)	20.1 (18.2; 22.8)	19.3 (17.7; 21.1)	21.3 (19.2; 24.6)	**<0.001**	26.6 (22.2; 32.7)	25.1 (21.2; 28.8)	29.1 (23.6; 35.8)	**<0.001**
Total energy (kJ/day)	11,123 (8437; 14,284)	11,305 (8709; 14,153)	11,042 (8234; 14,705)	0.878	9438 (6258; 14,686)	9955 (6756; 15,799)	8720 (5960; 12,284)	**0.001**
Total protein (g/day)	65.6 (49.7; 86.3)	68.9 (49.8; 88.3)	64.3 (49.4; 83.9)	0.227	63.2 (42.7; 90.9	67.4 (48.1; 96.6)	55.4 (38.0; 82.2)	**0.025**
Plant protein (g/day)	34.3 (25.6; 47.4)	35.9 (27.6; 48.3)	33.3 (24.7; 45.7)	**0.010**	27.4 (18.5; 41.9)	30.9 (19.5; 45.6)	24.9 (17.9; 36.6)	**0.013**
Animal protein (g/day)	29.5 (18.9; 41.8)	29.8 (18.5; 39.9)	29.5 (19.2; 43.3)	0.842	31.1 (19.4; 48.0)	34.6 (24.5; 48.5)	27.6 (17.5; 45.7)	0.318
Total fat (g/day)	97.2 (70.9; 142.9)	95.7 (70.4; 134.6)	100.8 (73.9; 144.6)	**0.024**	85.6 (50.6; 135.1)	86.7 (51.4; 139.0)	84.2 (50.5; 130.3)	**<0.001**
SFA (g/day)	24.1 (16.9; 35.1)	23.2 (16.6; 33.6)	24.9 (17.2; 36.9)	**0.010**	21.6 (13.3; 33.9)	21.5 (13.8; 34.9)	20.5 (12.7; 33.3)	**<0.001**
MUFA (g/day)	28.7 (19.1; 41.1)	28.7 (19.1; 39.6)	28.7 (19.1; 42.5)	0.468	21.8 (15.7; 40.9)	26.87 (16.9; 40.8)	24.9 (15.2; 40.9)	**0.002**
PUFA (g/day)	32.9 (20.1; 49.5)	33.1 (20.3; 47.4)	32.8 (20.1; 53.9)	0.109	24.1 (14.9; 40.9)	25.3 (15.0; 42.3)	22.5 (14.9; 39.4)	**0.003**
Carbohydrate (g/day)	352.3 (257.6; 436.6)	366.0 (282.4; 436.7)	341.3 (249.5; 433.5)	**0.031**	284.4 (187.4; 416.1)	315.3 (194.9; 465.9)	264.3 (183.2; 366.4)	0.460
Added sugar (g/day)	70.7 (44.0; 113.2)	70.6 (45.9; 117.8)	70.9 (42.6; 106.6)	0.227	56.6 (32.1; 95.9)	55.4 (28.9; 101.6)	59.4 (35.7; 88.4)	**0.004**
EI/EER ratio (kJ/day)	1.18 (0.88; 1.51)	1.11 (0.82; 1.39)	1.31 (0.96; 1.70)	**0.007**	1.003 (0.64; 1.54)	1.06 (0.64; 1.72)	0.96 (1.34; 0.65)	0.161

Significant results presented in bold ($p < 0.05$); [a] t-test; BMI = Body Mass Index; IQR = Interquartile range; SFA = Saturated fat; MUFA = Monounsaturated fat; PUFA = Polyunsaturated fat; EI-EER = Estimated intake and estimated energy requirements.

6.3.2 *Nutrient patterns*

Four similar nutrient patterns were extracted at the baseline visit, 12-month follow-up and 24-month follow-up from the principal component analysis among peri-urban adolescents and adults and named according to the nutrients with the highest factor loadings as indicated in (Figure 3). The four nutrient patterns cumulatively explained 71.50% and 69.04% at baseline, 66.03% and 64.62% at 12 months follow-up, and 61.15% and 64.90% at 24 months follow-up of the total variance in adolescents and among adults, respectively.

For adolescents and adults, the first PC retained had higher loadings of plant protein, starch, dietary fibre, iron, magnesium, zinc, vitamin B6, riboflavin, thiamine and folate over the 24 months. It was named “Plant driven nutrients”. The second PC was named “animal driven nutrients” because it had high positive loadings of vitamin B12, vitamin D, cholesterol, phosphorus, riboflavin, animal protein, phosphorus, calcium, retinol, saturated fat, monounsaturated fat, and folate over the 24 months. The third PC was named “fat-driven nutrients.” This nutrient pattern had high positive loadings of saturated fat, monounsaturated fat, polyunsaturated fat, cholesterol, retinol, animal protein and vitamin E. The fourth extracted PC had high loadings of animal protein, calcium, potassium, phosphorus, monounsaturated fat, polyunsaturated fat, vitamin B12, vitamin E, vitamin D and vitamin C. Because of these positive loadings, this nutrient pattern was named “Plant and Dairy driven nutrients” (Figure 18). Factor loadings ≥ 0.47 were used for naming nutrient patterns.

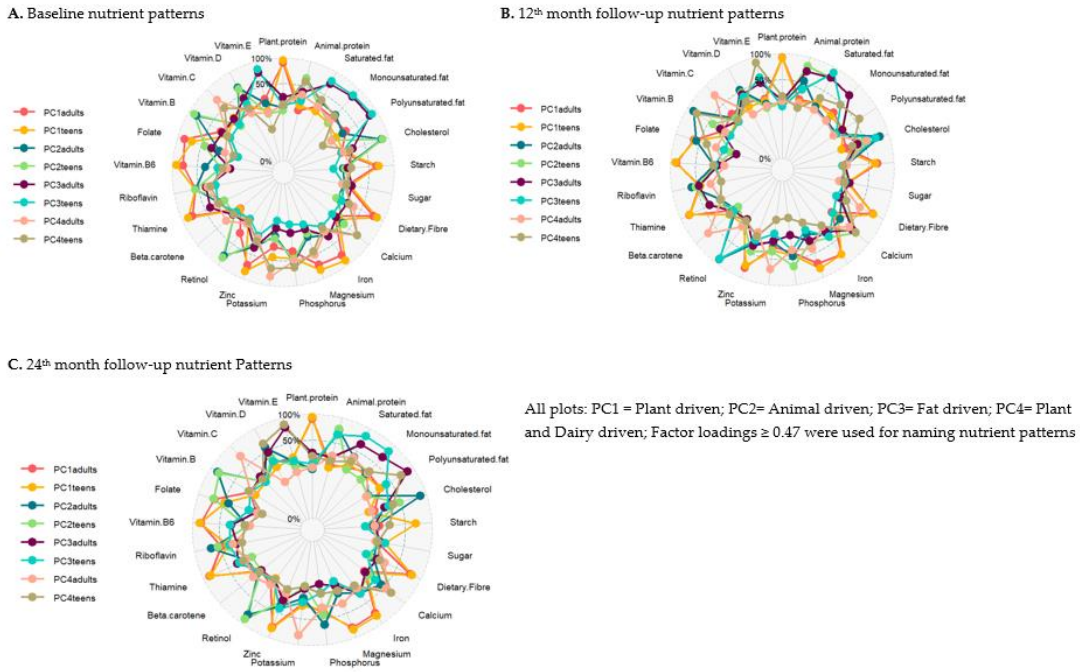


Figure 18: *Nutrient patterns factor loadings showing the nutrients driving the nutrient patterns in Black South African adults and teens.*

6.3.3 *Nutrient Pattern Associations with BMI*

The association results of the extracted nutrient patterns and BMI are shown in **Figure 19** and **Supplementary Tables 2-7**. for peri-urban adolescents and adults. A standard deviation changes in the "Plant driven nutrients pattern" was significantly associated with a 0.56 kg/m^{-2} (95% CI (0.33; 0.78); p= 0.000) increase in BMI among adolescents, as shown in **Figure 19A**. There was a significant sex*plant driven nutrient pattern interaction for BMI, with the association being significant in adolescent girls only (0.81 kg/m^{-2} (95% CI: 0.46; 1.15) p= 0.054) as illustrated in **Figure 19C**. In adults, the "plant-driven nutrient pattern" and the "fat-driven nutrient pattern" were associated with an increase in BMI, as illustrated in **Figure 19B**.

A standard deviation change in the "plant-driven nutrient pattern" was significantly associated with 0.43 kgm^{-2} (95% CI (0.03; 0.85); p= 0.000), and "fat-driven nutrient pattern" was significantly associated with 0.18 kgm^{-2} (95% CI (0.06; 0.29); p= 0.000) increase in BMI for all adults. Further analysis revealed that there was a significant sex*plant driven nutrient pattern interaction for BMI, with the association being significant in women (0.34 kg/m^{-2} (95% CI: 0.03; 0.69) p= 0.011), and a considerable sex*animal driven nutrient pattern interaction and sex*fat driven nutrient pattern interaction for BMI, with the association being significant in men (0.88

kgm^{-2} (95% CI (0.51; 1.25)) p= 0.000) and (0.45 kgm^{-2} (95% CI (0.09; 0.80)); p= 0.013) as shown in **Figure 19D**, respectively.

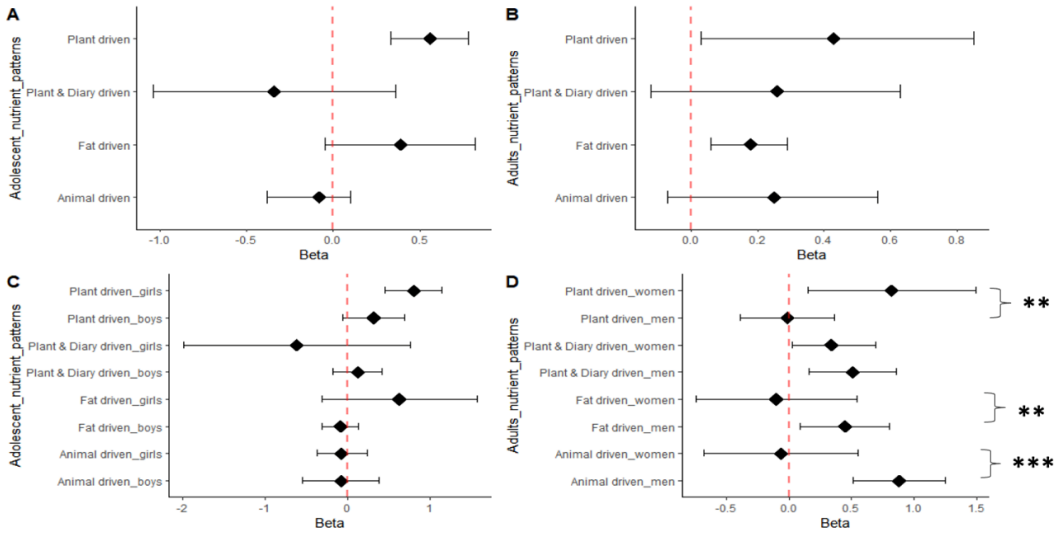


Figure 19: *Sex differences in the association of nutrient patterns with BMI.*

(**A**)**.** Nutrient pattern associations of nutrient patterns with BMI in SA adolescent boys and girls. (**B**)**.** Nutrient pattern associations of nutrient patterns with BMI in SA men and women. (**C**)**.** Sex–stratified nutrient patterns in adolescents. A significant sex*plant driven nutrient pattern on BMI was noted at ($p < 0.05$). (**D**)**.** Sex–stratified nutrient patterns in adults. All associations are adjusted for age, gender, household socio-economic status and energy intake reporting. A significant sex*plant–driven nutrient pattern on BMI was noted at ** ($p < 0.01$), the sex*animal–driven nutrient pattern on BMI was noted at *** ($p < 0.001$) and the sex*fat–driven nutrient pattern on BMI was noted at ** ($p < 0.01$).

6.4 Discussion

We set out to identify and compare nutrient patterns changes in black South African adolescents and adults over a period of 24 months, and to assess how these changes associate to participants' body mass index. At baseline, the extracted nutrient patterns explained 71.50% and 69.04% of the total variance in adolescent and adult nutrient intakes, respectively; at 12 months follow-up, they explained 66.03% and 64.62%; and at 24 months follow-up, they explained 61.15% and 64.90%. While the nutrient patterns of adolescents and adults were comparable over time, their associations with BMI were distinct. Only the "plant-driven

nutrients pattern" was significantly and positively associated to an increase in BMI of 0.56% (95% CI (0.33; 0.78); p≤0.001) in adolescents. Among adults, both the “plant-driven nutrient pattern” (0.43% (95% CI (0.03; 0.85)); p< 0.001) and the “fat-driven nutrients pattern” (0.18% (95% CI (0.06; 0.29)); p<0.001) were significantly and positively associated with an increase in BMI. Additionally, sex differences in the associations of the "plant-driven nutrient pattern," "fat-driven nutrient pattern," and "animal driven nutrient pattern" with BMI were observed. Notably, the "plant-driven nutrient pattern" and BMI had a positive and significant relationship in adolescent girls and women but a negative and non-significant relationship in adolescent boys and men. Contrarily, only in men compared to women were the animal and fat-driven nutrient patterns more positively and significantly associated with BMI.

There are no studies that, to the author's knowledge have evaluated the longitudinal association between nutrient patterns and BMI in Black South African adolescents and adults. According to the findings of our study, urban adolescents of both sexes consume a diet that is predominantly plant-based in terms of its nutrient composition. On the contrary, Pisa et al. (2015) (224) found that adolescents in rural areas consumed "animal-derived nutrients" the most. This implies that adolescents' dietary habits are affected by their location and socioeconomic status (urban vs. rural). As reported by other research, rural areas are undergoing a rapid nutrition transition, and as a result, a higher intake of animal protein, fat, and added sugar has been observed (356), which further supports the disparity between the results of the current study and those of Pisa et al., (224) among adolescents. Nonetheless, the adult nutrient patterns presented in this study, which show that plant-based nutrients are consumed the most, are consistent with those reported (345) among middle-aged men and women and by Makura-Kankwende et al., (346, 347) among middle-aged women residing in urban South Africa. The similarity between the patterns presented in this study and those presented in previous studies on adults (345-347) is due to the fact that they were all conducted on urban-dwelling adults, indicating that the nutrient patterns among adults in cities are broadly applicable. Furthermore, the differences in nutrient patterns intake between rural and urban adolescents and the similarities between urban adolescents and adults reveals that city dwellers have different nutrient intake patterns than rural residents. Consequently, this also implies that nutrient patterns of urban and rural dwellers will vary in

their relation to body mass index. This variation highlights the need to factor in the impact of context on nutrient patterns whenever designing interventions.

A comparison of the nutrient patterns of adults and adolescents was conducted, and we observed that over the two years that the study was done, the patterns stayed the same, with the plant-based nutrient pattern being the most consumed overall. This consistency and similarity show that urban households consume diets that contain comparable foods and supports the finding that the plant-based nutrient pattern is most consumed in urban South Africa (339). But, as a result of adolescents' low BMI that made it difficult to detect associations at a young age, we also observed that the relationship between nutrient patterns and BMI was more pronounced in men and women than in boys and girls. However, given the similarities of nutrient patters between adults and adolescents in this study over time, the nutrient patterns of urban dwellers can be generalized regardless of age. Furthermore, because of their consistency and homogeneity over time, interventions to promote healthy dietary intake can begin in adolescence and continue into adulthood. Findings of this research supports the notion that adolescence is a critical time to influence positive behaviours change in order to improve both immediate and long-term health outcomes (357).

Noteworthy gender differences were observed in the association between nutrient patterns and BMI. The plant-driven pattern's association with BMI varied by sex, with women showing a stronger association than men. This is consistent with previous cross-sectional findings in urban men and women (345). Interestingly, our findings show that this relationship emerges during adolescence, with adolescent girls in the present study also showing a significant association between the plant-driven pattern and BMI, a previously unknown finding. On the contrary, the association between animal-driven and fat-driven nutrient patterns and BMI was found to be stronger in men than in women. A finding that is similar to that reported in previous cross-sectional research (345). This is also in line with reports on black households in South Africa, which found that male dietary needs are given higher priority than those of women and children, especially when it comes to meals that contain high amounts of protein, such as meat-based meals (352). Most importantly, these associations point to a shift toward

Westernized diets that are high in energy-dense foods (351, 352). In turn, this means that men have a higher risk of developing non-communicable diseases than women.

The current study's strengths are its longitudinal design, the use of a validated and comprehensive QFFQ, and the assessment of nutrient patterns in both adolescents and adults. Longitudinal nutrient evaluation has several benefits, including the ability to identify stability and compare similarities between adolescents and adults. Despite the subjective nature of pattern interpretation and labelling, the PCA technique is well established for capturing real-life dietary behaviours (224, 344). One limitation of our study was that we did not collect data on participants' levels of physical activity beyond what was captured by the QFFQ. However, the EI/EER ratio was used to adjust participants' self-reported energy intake to reduce dietary reporting bias. Furthermore, it is not possible to generalize or extrapolate the relationships shown between nutrient patterns and BMI to people living in rural areas because the data presented is restricted to urban areas only. Because of this, investigations are required to consist of data gathered from both urban and rural areas.

6.5 Conclusions

To conclude, the nutrient patterns of urban adolescents and adults are comparable, and while there are age and gender differences in their association with BMI, their consistency over time suggests that nutrition interventions aimed at improving health outcomes can start earlier, in adolescence. The current findings highlight the significance of taking gender differences into account and the significance of addressing both girls' and boys' health-related behaviours, which has implications for future efforts to improve preconception health through nutrition. They can serve as a starting point for developing nutrition interventions that aim to address the health needs of adolescents and, in turn, address the issue of maternal and child mortality, as well as prevent the risk of chronic diseases in adulthood and future generations. Moreover, our findings provide insightful data that can be used monitor progress and help revise the current South African Strategy for the Prevention and Control of Obesity (2015–2020). Our recommendation is that future longitudinal studies examine the relationship between the nutrient patterns and body mass index of rural residents in order to gain a deeper understanding of their dietary behaviours and ensure no one is left behind, as the current

study only examined urban residents. By doing so, South Africa would make significant progress in battling obesity and chronic NCDs, as it will aid the development and implementation of national level interventions.

Table 12 Supplementary. *Longitudinal associations of nutrient patterns and BMI in adolescents*

Variables	**B (95% CI)**	**p-Value**
Age (years)	0.33 (0.17; 0.58)	0.012
Male	-5.41 (-6.48; -5.24)	<0.001
Female (Ref)		
SES Categories		
Low	-0.33 (-0.70; 0.03)	0.027
High (Ref)		
IE/EER		
Under reporting	0.21 (-5.13; 5.55)	0.937
Over reporting	-0.70 (-3.08;1.68)	0.565
Plausible (ref)		
PC1	0.56 (0.33; 0.78)	<0.001
PC2	-0.38 (-0.08; 0.01)	0.138
PC3	0.39 (-0.05; 0.82)	0.081
PC4	-0.34 (-1.04; 0.36)	0.343

Significant values are p ≤ 0.05; SES = household socio economic status; IE/EER = estimated energy intake and estimated energy requirements; PC1 = Plant driven nutrients; PC2 = Animal driven nutrients; PC3 = Fat driven nutrients; PC4 = Mixed, Plant and diary driven nutrients; B = beta coefficient; CI = confidence interval.

Table 13 Supplementary*. Longitudinal associations of nutrient patterns and BMI in adults*

Variables	**B (95% CI)**	**p-Value**
Age (years)	0.12 (0.09; 0.14)	<0.001
Male	-6.67 (-6.79; -6.54)	<0.001
Female (Ref)		
SES Categories		
Low	1.12 (0.92; 1.31)	<0.001
High (Ref)		
IE/EER		
Under reporting	7.53 (4.90; 10.16)	<0.001
Over reporting	2.89 (0.44; 5.36)	0.021
Plausible (ref)		
PC1	0.43 (0.03; 0.85)	0.043
PC2	0.25 (-0.07; 0.56)	0.130
PC3	0.18 (0.06; 0.29)	0.002
PC4	0.26 (-0.12; 0.63)	0.182

Significant values are p ≤ 0.05; SES = household socio economic status; IE/EER = estimated energy intake and estimated energy requirements PC1 = Plant driven nutrients; PC2 = Animal driven nutrients; PC3 = Fat driven nutrients; PC4 = Mixed, Plant and diary driven nutrients; B = beta coefficient; CI = confidence interval.

***Table 14 Supplementary**. Longitudinal associations of nutrient patterns and BMI in girls.*

Variables		**B (95% CI)**	**p-Value**
Age (years)		0.69 (0.51; 0.81)	<0.001
SES Categories			
Low		0.43 (-0.15; 1.03)	0.148
High (Ref)			
IE/EER			
	Under reporting	0.21 (-6.01; 5.52)	0.957
	Over reporting	-0.58 (-3.08;1.68)	0.531
	Plausible (ref)		
PC1		0.76 (0.33; 0.88)	<0.001
PC2		-0.12 (-0.27; 0.28)	0.664
PC3		0.39 (-0.21; 1.21)	0.187
PC4		-0.41 (-1.91; 0.38)	0.382

Significant values are p ≤ 0.05; SES = household socio economic status; IE/EER = estimated energy intake and estimated energy requirements; PC1 = Plant driven nutrients; PC2 = Animal driven nutrients; PC3 = Fat driven nutrients; PC4 = Mixed, Plant and Diary driven nutrients; B= beta coefficient; CI = confidence interval.

***Table 15 Supplementary**. Longitudinal associations of nutrient patterns and BMI in boys.*

Variables		**B (95% CI)**	**p-Value**
Age (years)		0.08 (0.04; 0.13)	<0.001
SES Categories			
Low		-1.39 (-1.58; -1.21)	<0.001
High (Ref)			
IE/EER			
	Under reporting	0.24 (-5.07; 5.57)	0.928
	Over reporting	-0.69 (-3.08;1.68)	0.565
	Plausible (ref)		
PC1		0.32 (-0.02; 0.69)	0.102
PC2		-0.12 (-0.47; 0.32)	0.768
PC3		-0.10 (-0.17; 0.21)	0.486
PC4		0.21 (-0.01; 0.36)	0.399

Significant values are p ≤ 0.05; SES = household socio economic status; IE/EER = estimated energy intake and estimated energy requirements; PC1 = Plant driven nutrients; PC2 = Animal driven nutrients; PC3 = Fat driven nutrients; PC4 = Mixed, Plant and Diary driven nutrients; B= beta coefficient; CI = confidence interval.

***Table 16 Supplementary.** Longitudinal associations of nutrient patterns and BMI in women*

Variables		**B (95% CI)**	**p-Value**
Age (years)		0.17 (0.08; 0.26)	<0.001
SES Categories			
Low		0.29 (-1.34; 1.93)	0.384
High (Ref)			
IE/EER			
	Under reporting	9.42 (7.05; 11.78)	0.003
	Over reporting	4.32 (1.63; 7.01)	<0.001
	Plausible (ref)		
PC1		0.82 (0.15; 1.49)	0.015

PC2	-0.06 (-0.68; 0.55)	0.838
PC3	-0.10 (-0.74; 0.54)	0.754
PC4	0.07 (0.03; 0.69)	0.821

Significant values are p ≤ 0.05; SES = household socio economic status; IE/EER = estimated energy intake and estimated energy requirements PC1 = Plant driven nutrients; PC2 = Animal driven nutrients; PC3 = Fat driven nutrients; PC4 = Mixed, Plant and diary driven nutrients; B = beta coefficient; CI = confidence interval.

***Table 17 Supplementary**. Longitudinal associations of nutrient patterns and BMI in men*

Variables	**B (95% CI)**	**p-Value**
Age (years)	0.06 (0.02; 0.11)	0.004
SES Categories		
Low	1.06 (-1.25; 3.37)	0.368
High (Ref)		
IE/EER		
Under reporting	5.87 (4.29; 7.44)	<0.001
Over reporting	1.88 (0.34; 3.41)	0.017
Plausible (ref)		
PC1	-0.01 (-0.39; 0.36)	0.943
PC2	0.88 (0.51; 1.25)	<0.001
PC3	0.45 (0.09; 0.80)	0.013
PC4	0.51 (0.16; 0.86)	0.004

Significant values are p ≤ 0.05; SES = household socio economic status; IE/EER = estimated energy intake and estimated energy requirements PC1 = Plant driven nutrients; PC2 = Animal driven nutrients; PC3 = Fat driven nutrients; PC4 = Mixed, Plant and diary driven nutrients; B = beta coefficient; CI = confidence interval.

Part 3: Integrated Discussion and Conclusion

“Health is made at home and is a result of many sectors' direct or indirect interventions.”

- Dr Stefan Peterson, Chief of Health at UNICEF

Chapter 7: Integrated Discussion and Conclusion

This chapter summarizes the findings from the preceding chapters in relation to the thesis's primary objectives. It then identifies and discusses the major themes that emerged from the analyses, followed by reflections on the empirical contributions of the thesis and a review of the employed conceptual framework. Before reflecting on the strengths and weaknesses of this thesis, a discussion of the implications of the findings and recommendations for future research are presented.

7.1 Key findings

This thesis objective was to examine the individual, household, and environmental factors that influence adolescents' health-related behaviour, specifically dietary and physical activity habits, and to identify ways in which these factors can be leveraged to better ensure the health of future generations, particularly during the crucial preconception years. To answer the research questions and hypothesis presented in Chapter 1, four objectives emerged, and the resulting findings are shown in Table 18.

Table 18. *Consolidated findings and conclusion for the study.*

Chapter	Objective	Key findings
3	**Objective 1:** To examine the relationship between household socioeconomic status (SES), dietary knowledge and patterns, and level of physical activity, and body mass index (BMI) in urban South African young women.	1. The findings suggests that the prevalence of overweight and obesity among young women is independent of SES. 2. As expected, age was positively associated with BMI. 3. SES and dietary knowledge have no association with BMI. 4. The mixed dietary pattern was inversely and significantly associated with BMI. 5. ≥ 150 minutes of MVPA per week is inversely and significantly associated with BMI.

4	**Objective 2:** To explore young adults' barriers to healthy eating, physical activity, and the solutions to address these barriers with an intersectionality perspective.	1. South African young adults have a basic understanding of the significance of nutrition, exercise, and their ties to health. 2. Factors at the individual, neighbourhood, societal, and community levels were found to have a significant impact on the participants' preferences of lifestyle behaviours (such as consuming nutritious food and exercising regularly). 3. The findings indicate that young women face these hurdles to a greater extent than young men, suggesting that there are gender disparities in how these barriers affect young people.
5	**Objective 3:** To explore Soweto's young people's knowledge and perceptions of COVID-19 and its effects on their lives, including access to healthy nutrition and physical activity opportunities, and mental health, for over six months during the pandemic.	1. Young people's understanding of COVID-19 deepened throughout the study, however, did not always translate into adherence. 2. Access to healthy food was impeded by household heads loosing their livelihoods. Numerous young people frequently worried about their future, particularly their education. In addition, movement limitations promoted more screen time and sedentary behaviour. 3. Parents, teachers, and schools were trusted sources of information. In the media, teenagers preferred the TV and radio over internet for COVID-19 related information. 4. The minimal risk perceptions and conspiracy theories influenced non-adherence among young men.
6	**Objective 4:** To describe and compare the nutrient patterns of urban adolescents and adults at three time points (baseline, 12-month follow-up, and 24-month follow-up), evaluate if they changed over the 24-month period, and determine their relationship with adiposity (BMI).	1. The nutrient patterns between adolescents and adults were similar over time. 2. The "plant driven nutrients pattern" was significantly associated with BMI in adolescent boys and girls. 3. The "plant-driven" and the "fat-driven" nutrients patterns were significantly associated with a BMI increase in men and women. 4. The "plant-driven nutrient pattern" was strongly associated with BMI in women and girls. 5. The "fat-driven" and the animal-driven" nutrients patterns association with BMI was stronger in men, but this was not observed in boys.

7.2 Emerging Themes

This section discusses the themes uncovered by the research. It is divided into two major sections: the first addresses methodological themes that emerged from the studies, and the second address's empirical themes.

Every step of the research process was carefully planned, from the first cross-sectional quantitative study assessing dietary patterns, to the focus group discussions with young people about the barriers to healthy nutrition and physical activity and the possible solutions, their perceptions on the COVID-19 pandemic and its impact, to the final prospective cohort study on nutrient patterns and statistical analyses.

7.2.1 Methodological theme

Mixed methods

Several methods were considered when designing the series of studies comprising this thesis to identify the factors affecting the adoption of lifestyle behaviours (dietary and physical activity habits) known to be beneficial to health and to describe their association with the nutritional status of adolescents.

Traditional attempts to combine qualitative and quantitative approaches frequently combined quantitative and qualitative approaches without providing a clear rationale for method selection and have frequently lacked a solid methodological foundation in research practice. To make matters worse, when combining qualitative and quantitative data, it is not always easy to make sense of the results. A mixed-methods approach, on the other hand, excels at reconciling disparities between quantitative and qualitative findings. To sum it all up, this results in a richer, more comprehensive body of evidence and a more thorough understanding of the issue at hand.

Both qualitative and quantitative methods were used in this thesis. This was done to make up for the fact that both research methods have weaknesses that overlap. As a result, rather than being determined solely by methodological and epistemological considerations, the research questions posed determined the methods used in this series of studies. In this way, the methods chosen were intended to bring together various types of evidence to improve the

studies' ability to explain things. It was not an easy decision to use a mixed-methods approach, but it proved to be the best option in achieving the main objective of this thesis. While I was already confident in conducting quantitative analysis at the beginning of my thesis journey, the same could not be said of my ability to conduct qualitative analysis, which was a bit of a challenge. But as I kept working on this thesis, I learned some new and very helpful skills through reading the literature and working with my supervisor and other researchers. One of these newly learned skills was the ability to conduct a thematic analysis. Because of this experience, I can now easily point out the problems with each of these methods when I'm trying to answer specific research questions, like what makes people start living a healthy lifestyle. The various strengths and challenges related to the mixed methods approach utilized in this thesis are summarized and displayed in Table 19 below.

Table 19. *Summary of strength and challenges of using a mixed methods approach.*

	Quantitative components	**Qualitative components**
Strength	• The quantitative elements allowed the hypotheses testing of the different factor's contribution to young adults' poor nutritional status. • The QFFQ used for dietary intake assessment is useful for retrospectively estimating longer-term typical food intakes, ranking participants according to their intake levels, and estimating foods consumed irregularly. • The quantitative elements allowed the use of different methods of analysing dietary intakes. The whole food approach and the nutrient pattern approach were used for describing participants dietary intakes. • Findings from using the whole-food approach can be very useful in informing public health interventions to highlight foods that contribute to malnutrition.	• The qualitative component significantly deepened our understanding of participants' difficulties in adopting healthy lifestyle behaviours despite their knowledge of the health benefits. • It allowed the description of participants feelings and their perception of lifestyle driven health challenges. • It helped us to realize and better understand that participants have concurrent challenges to healthy living and that this needs to be considered when designing interventions.

	• The prospective cohort study, which followed the nutrient patterns approach allowed comparisons between adults and adolescents, making the results more comparable to other settings and generalizable to urban settings in South Africa.	
Challenges	• The statistical results were not able to provide the human motivation behind certain lifestyle preferences and behaviours. • The dietary assessment tool (QFFQ) relies on subjects' recall of food intake and tends to under-report or over-report. • The QFFQ is susceptible to measurement error. Cognitively, it is difficult to answer the frequency of common input questions. Also, the amount of food that can be queried is limited and many details on how the food is prepared are not collected. • Since people eat different foods, the whole-foods analysis makes it difficult to make cross-cultural or cross-country comparisons and generalizing findings between populations living in different context. • Analysis of nutrient patterns does not help inform public health policies and interventions because the foods that contribute nutrients are not explicitly assessed, only the nutrients. • Also, software algorithms are required to convert frequencies to nutrients.	• One of the hardest parts of doing qualitative research is choosing the right cases and making sure they can be transferred to other situations. This is because small sample sizes and context-specificity make it hard to be representative and generalize. • The method of data collection (FGDs) depends on the willingness and ability of respondents to dedicate time which was often difficult to schedule with adolescents. • Engaging young adults via virtual platforms during the peak of the COVID-19 pandemic emerged as one of the biggest barriers, as data collection depended on participants' access to internet-connecting devices, meaning that only those with access could participate in FGDs. • There is no set method for conducting the qualitative component; rather, researchers must rely on their own judgment and creativity as they gather, interpret, and analyse data. • It will not be possible to conduct the same research and obtain similar findings at any other time or location. In other words, qualitative component is not replicable as opposed to quantitative component.

7.2.2 Empirical themes

In writing this thesis and employing both quantitative and qualitative research methods to analyse the data, the findings reveal that adolescents and young adults are susceptible to poor health conditions that are primarily influenced by their context. Specifically, our findings indicate that the context of adolescents and young adults significantly influences their choice of lifestyle behaviours, particularly the type of diet they consume and whether or not they will participate in physical activities. Through both cross-sectional and longitudinal quantitative data, we were able to identify dietary and nutrient patterns associated with poor nutritional status. These patterns consisted of high intakes of added sugar, fats, processed meat, carbohydrates, and red meat, as well as low intakes of fruits and vegetables, which are foods typically associated with an adiposity-promoting western diet. Following this, the qualitative analysis, which also included cross-sectional and longitudinal data, allowed us to determine that, due to their context, which includes household, neighbourhood, and community, adolescents and young adults in the Soweto context face a number of multilevel barriers that influence their decision to adopt a healthy lifestyle, including healthy eating and physical activity. As shown in the Lancet series of adolescent nutrition framework (52) (figure 4), we are aware that the food environment is shaped by cultural, economic, commercial, and environmental ecosystems that extend to the family and community settings in which adolescents develop . In discussions with young adults, lack of resources (money) to purchase healthy food at home and stigma by peers in relation to their weight loss being compared to a sick person with HIV/AIDS were cited as significant influences on their choice of poor health-related behaviour. Issues such as these are essential for demonstrating the varying levels of influence, which our data indicates are sometimes the result of the adolescents' relationships and sometimes their lack of resources at a household level. However, it is important to note that the adolescent faced all of these obstacles simultaneously. In addition, the qualitative component demonstrates that certain stressors beyond the control of adolescents and young adults, such as the recent COVID-19 pandemic outbreak, exacerbate their poor health conditions. Due to the urban poverty situation in Soweto, our qualitative findings indicate that the adolescents and young adults living there were not sufficiently insulated against the pandemic's shocks. Because of the COVID-19 pandemic, many adolescents and young adults spent the majority of their time worrying and being afraid of losing loved ones, contracting the COVID virus, and their future, which contributed to an increase in the prevalence of mental

health disorders among South African youth (358, 359). In addition, the majority of young adults or their families' livelihoods were affected by economic shocks as a result of the COVID-19 pandemic, and they had so few resources to an extent that many households were food insecure (360), showing that eating healthily is not a priority when you have very little to none resources. This lead to an understanding that for many young people, immediate challenges are more pressing than those with future health related consequences.

The qualitative data also helped with gaining an understanding that some solutions are only suitable for addressing a single challenge while leaving unaddressed several others. The discussions we had with young people tell us that as a result of the movement restrictions (lockdown) imposed by the government to control the spread of the virus, adolescents and young adults could no longer engage in physical activities such as playing soccer or walking with friends in the parks. These activities have been associated with a variety of health benefits, including mental (361) physical health and a reduction in COVID-related hospitalisation risks (362). It goes without saying that the COVID-19 pandemic caught the entire world unprepared, particularly in terms of protecting young people from the mental health shocks caused by a global health crisis, and the effects of this will continue to be more pronounced as young people age. Consequently, both the quantitative and qualitative components were very important in leading to the findings of this thesis, which provide some answers to the gaps in knowledge and an overview of the health needs of adolescents and young adults living in poor settings such as Soweto and facing multiple barriers to healthy nutrition and physical activity engagement, amongst others such as poor service delivery, a poor and overburdened health system, economic exclusion, rapid changes as they transition into adulthood, and a life-threatening global pandemic. In addition, the observation of poor dietary habits among adults is consistent with the life-course approach concept that poor health-related behaviour is likely to persist into adulthood. In order to improve the preconception health of adolescents and young adults, we must design interventions that consider the various intersecting barriers when promoting healthy lifestyle behaviours and improving their mental health.

7.3 Conceptual framework

This section provides some introspection on the conceptual framework that was introduced at the beginning of this study series and served as its basis. The developed framework (Figure 5) was useful, and the results in this thesis have reaffirmed it. In addition, the results of this thesis have added new information highlighting that young people are being affected by co-occurring barriers that are intersecting making the adopting of health-related behaviour difficult. The red arrows denote the intersectionality of the factors at different levels of context, and the red circle denotes that they have simultaneous effects on the adolescent.

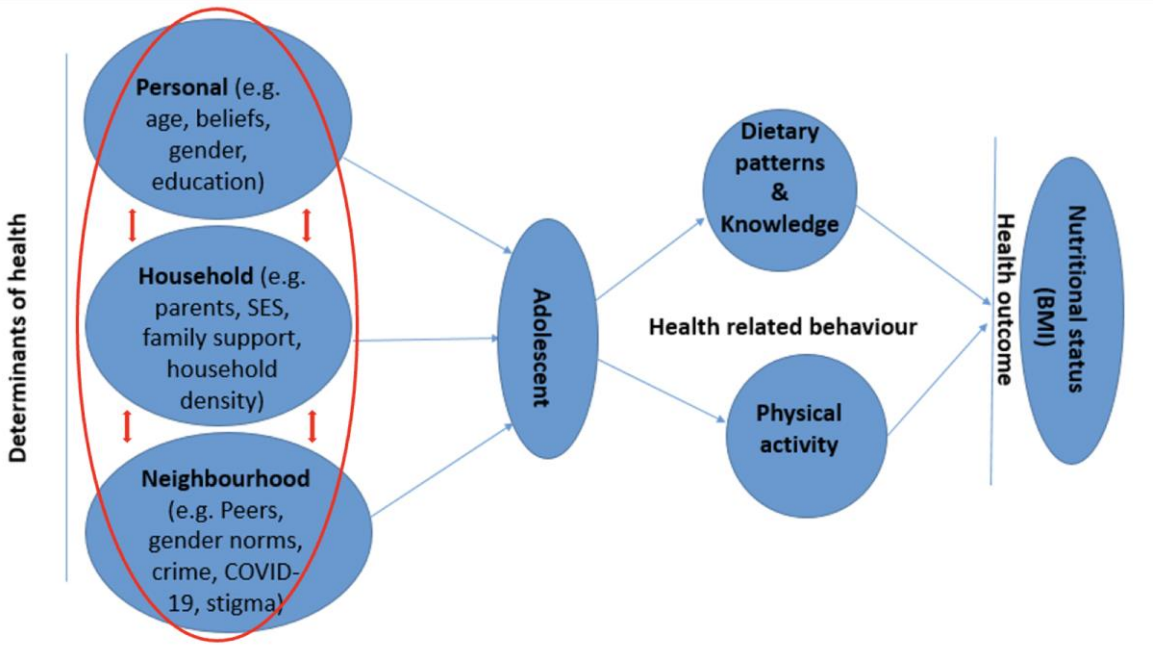


Figure 20: *Modified thesis conceptual framework for the health determinants of adolescent health, behaviours, and health outcome of focus.*

7.4 Implications

- This thesis has provided the groundwork for understanding the literature related to the nutritional status of adolescents in urban South Africa and their risk of noncommunicable diseases in comparison to the prevalence of NCDs worldwide. It has also highlighted the various policies and strategies that sought to include adolescent health needs in the context of South Africa while addressing specific knowledge gaps of various factors such as the impact SES and the barriers to healthy eating and PA engagement arising at a personal level, the home and neighbourhood environments

that contributes the adolescent's lifestyle behavioural patterns (dietary intakes and physical activity).

- The findings highlight that regardless of SES, the risk to adiposity and NCDs is similar. However, context (i.e., living in a rural or urban area) does contribute significantly in terms of the health-related actions individuals can make which in most cases are forced actions due to circumstances. This is important as it supports the need to consider the intersectionality of the various factors that contribute to individuals' behavioural choice as that will help improve interventions and policies.
- The findings of this series of studies are the first of their kind in the context of South Africa. They attempt to build on various types of evidence to demonstrate the link between modifiable lifestyle behaviours that determines health (dietary and physical activity habits), and young adults' nutritional status in order to determine how they can be leveraged to improve preconception health.
- The prospective cohort study has highlighted significant findings that shows gender differences in terms of dietary intakes and adiposity, whereby the dietary behaviour associated with weight gain in women has also been observed in girls. This finding is important for informing intervention designing as it shows that not all interventions will have the same effects in men and women.
- Furthermore, this body of research has filled in some critical gaps in our knowledge in relation to the nutrient patterns of adolescents being comparable to those of adults over time using a prospective cohort study. These findings highlight the fact that nutrition interventions, particularly those designed to improve preconception health, can have more benefits if they are initiated during the adolescent period.

7.5 Future work

One of the most interesting elements that emerged from this thesis was the level of added sugar consumption among young people. As described in the preceding sections, the assessment method (QFFQ) used to determine dietary intake relied on subject recall, which is susceptible to under- or overreporting. In other contexts, stable isotope biomarkers have been used to show the correlation between added sugar and nutritional status as well as the related health implications (363, 364). With more research South African showing that added sugar

intake is not decreasing despite remedial actions such as the SSB tax (96, 123), there is a need to accurately assess the current added sugar consumption levels as such stable isotope biomarkers can be potentially capable of helping us achieve this (365). With this regard, there is a need to test the feasibility and accuracy of objective and subjective measures for added dietary sugar intake, and to explore the association between added dietary sugar intake and nutritional status and body composition in urban-poor South African young adults.

To achieve the above objectives, the research will have to assess three components:
(1) Test the use of the natural abundance carbon isotope ratio (CIR, 13C/12C) as a measure of added sugar intake in South African young adults and to compare the accuracy and practicality of using total CIR compared to CIR measured in the amino acid alanine (CIR-ala); and
(2) To validate the use of 24-hour recall to assess habitual added sugar intakes using doubly labelled water estimates of daily energy expenditure; and
(3) To explore the associations between added sugar intake (as measured by CIR) and nutritional status and body composition in young adults.

To gather all these data, a sample of 100 (50 men and 50 women) apparently healthy participants will be recruited to participate in a one-month period of data collection. Dietary intake will be evaluated by 24hr dietary recalls obtained weekly and on different weekdays, during the four subsequent weeks. Anthropometric measurements and breath samples for breath-CIR analysis will be obtained along with the 24hr diet recalls. The DLW method will be used to analyse energy expenditure in a subsample of 25 individuals during the third and fourth weeks. In addition, participants will be asked to provide an overnight urine sample and multiple breath samples the day before their appointment for the DLW method, for 14 days after receiving a DLW dose, and on the morning of their day visit if they are not a part of the DLW study. A venous blood and spot sample will be obtained on the last day of the one-month data collection period to analyse the serum total carbon isotope ratio and biochemical markers of NCDs.

To build on the current findings presented in this thesis, I am currently working with the International Atomic Energy Agency (IAEA) on a coordinated multi-country study with an aim of assessing added sugar intake in young adults using natural abundance carbon isotope ratio

(CIR, $^{13}C/^{12}C$) as a biomarker, which will also include validating the biomarker and 24hour dietary recalls with doubly labelled water (DLW) in our South African context.

7.6 Limitations

This thesis reviewed a significant body of literature pertaining to the health needs of adolescents and young adults. The literature covered topics such as adolescents' dietary and physical activity patterns, as well as their association with nutritional status and preconception health. This review was helpful in identifying knowledge gaps from the perspective of a South African context. However, since the World Health Organization (WHO) identified the adolescent period to start at age 10 (366), and the adolescent participants in this series of studies start at age 13 and above. This means there is still a data paucity in the age group that was not included in this series of studies, which can be critical in addressing some of the health challenges that adolescents currently face. Furthermore, in some instances, this thesis also had to rely on secondary data to address the identified knowledge gaps, which the author was not responsible for collecting. Moreover, the assessment procedures that were used for gathering quantitative data, such as the QFFQ for assessing dietary intakes and the GPAQ for assessing levels of physical activity, were all subjective recalls. Objective measures, such as using stable isotopic biomarkers, DLW, and accelerometers, would have been helpful in improving measurement accuracy and addressing concerns about under- and overreporting; however, access to these measures remains a challenge, particularly for researchers in LMICs due to the exorbitant financial resources required to purchase them.

7.7 Conclusion

In conclusion, adolescent preconception health, especially modifiable health-related behaviours such as diet and lifestyle, remain crucial research areas if we are to continue our efforts to reduce both maternal and infant mortality and safeguard future generations from chronic NCDs.

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Appendices

Appendix A: Paper 1 Information Sheet and Consent (Young women)

LEVERS FOR INTERVENTION FOR DIET AND PHYSICAL ACTIVITY IN YOUNG ADULTS AT VARYING SOCIO-ECOLOGICAL LEVELS

Hello, my name is Gudani Mukoma and I am a Researcher at the MRC/Wits Developmental Pathways for Health Research Unit (DPHRU) from the University of the Witwatersrand. I together with other researchers would like to invite you to participate in a research project of the above-mentioned title.

Before, agreeing to participate, it is important that you understand the purpose of the study, the study procedures, benefits, and risks as well as your right to withdraw from the study at any time. If you have any questions, do not hesitate to ask me. You should not agree to take part unless you are satisfied with all the procedures involved. If you decide to take part in this study, you will be asked to sign this consent form to confirm that you understand the study. You will also be given a copy to keep.

Where will the research be conducted?
All the research will be undertaken in your homes and some at the MRC/Wits DPHRU offices at Chris Hani Baragwanath Hospital should we have a follow-up with you.

What is the purpose of the research?
The aim of this study is to assess changeable factors for physical activity and diet, and how they differ by individual and household resources, by neighbourhood conditions and the connection between resources and conditions.

We are inviting young adults between the ages of 18-24 years, who do not have a child and must be living in Soweto to participate. We will only visit you once at your household.

Do I have to take part?
Your participation is voluntary. But even if you decide to take part you are still free to withdraw at any given time.

What are the procedures for the study?

<u>Measurements</u>
We will measure your blood pressure, height, weight, waist circumference, hip circumference and mid upper arm circumference which will be done by a trained research assistant in your home. This will take about 10 minutes. If we find that you have high blood pressure, we will let you know and provide you with a referral note for further clinical management.

<u>Urine collection</u>

We would like to collect a spot urine sample from you, which will be used to test for potassium (K) and sodium (Na) ratio. The spot urine sample will help us determine the ratio between sodium and potassium as an indicator of overall salt (sodium) intake to fruit and vegetable (potassium) intake.

<u>Questionnaires</u>

One of our trained research assistants will ask you a series of questionnaires, which will take about 60 minutes to complete. The questionnaires which we would like to go through with you are: Nutritional knowledge survey, Socio-demographic questionnaire, Food frequency questionnaire, Global physical activity questionnaire (GPAQ).

Food expenditure

We are going to ask you to keep till slips so that we can see how much is being spent on groceries in the household. If you don't receive a slip where you purchase, then we will provide you with a small booklet to keep that information.

Accelerometery

We will be measuring physical activity through the use of an accelerometer (a small device that measures your acceleration during movement) which will be placed on your wrist. We would like you to wear this continuously for a 7day period in order to capture 24-hour movement including physical activity, sedentary behaviour and sleep. We will also be asking you to record the time you go to bed and time you wake each day and night while wearing the monitor.

Neighbourhood Environment Walkability Scale (NEWS)

If you are selected to be trained to use the "Neighbourhood Discovery Tool" mobile app to map and describe neighbourhood level factors that impact your diet and physical activity. The mobile app data, which has been validated in this setting, will include you taking pictures, recordings and confirming the location within the community setting. You will be trained to capture data across a variety of media on what foods and drinks you are exposed to in your neighbourhood; and what things in your environment are relevant for and impact on (enablers and barriers) your food choices and physical activity.

Accompanied by a researcher, you will also be trained to capture where you spend time on an average weekday and weekend to cover all domains of physical activity opportunities (leisure, sport, travel). These conditions will include but are not limited to

- Shops, stalls, and retail outlets (restaurants, cafes)
- Advertising on billboards (food (healthy and otherwise), sugar sweetened beverages, alcohol)
- Advertising on radio or television (food (healthy and otherwise), sugar sweetened beverages, alcohol)
- What you eat and drink, and where you bought or were given the food items?
- What else is sold at the places where you buy food and drinks?
- Where you don't eat or spend time and why?

What would I be asked to do if I took part?

If you are happy participate in the research we will ask you to read this information sheet and sign the consent form.

Risks

There are no risks for taking part in this study. However, if you experience psychological distress or discomfort we do have a registered counsellor available that you could be referred to for initial consultation and she will best direct you to obtain assistance where applicable. Alternatively you can email or contact our counsellor via email or phone call on the details below:

Dr Tamsin Rochat (Clinical psychologist and associate professor); e-mail address: tamsen.rochat@wits.ac.za; Telephone: 011 933 2122

Benefits

There are no direct benefits to participating in this research project.

What happens to the data collected?
All information you provide to us will be kept confidential. Only members of the research team will have access to it. Information gained during the research will be used as part of a larger sample, and will remain anonymous. The outcomes of the research will be available in one or more of the following sources: scientific papers in peer reviewed academic journals, presentations at a regional conference, local seminars. The information collected about you may be stored and used to support other research in the future, and will be shared anonymously with other GDAR researchers including researchers in other countries.

Ethical approval
This study protocol has been submitted for ethical approval to the University of the Witwatersrand, Human Research Ethics Committee (HREC).

Who do I contact if I have any questions about the study?
If you have any questions or you experience any problems during or after the sessions, please contact Gudani Mukoma or a representative of the Human Research Ethics Committee.

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Chairperson of this Committee : Dr Clement Penny who may be contacted on telephone number 011 717 2301, or by e-mail on Clement.Penny@wits.ac.za. The telephone numbers fpr the secretariat are 011 717 2700/1234 and the e-mail adresses are Zanele.Ndlovu@wits.ac.za and Rhulani.Makansi@wits.ac.za

Consent to participate in the study: Young women

"I, _____, hereby give consent to participate in this research to be conducted by DPHRU

I understand that the study will involve completion of a series of questionnaires and wearing an accelerometer device for 7 days. The purpose and all the details of this study have been explained to me.

I have read and have had explained to me the procedures described. I have had an opportunity to ask questions and my questions have been answered in a satisfactory way.

I understand that all the information collected during the study will be treated with the strictest confidentiality and will only be used for scientific research purposes. All records will be kept in a locked room and in a secure computer database in the research unit. My name will not be used in any publication of the results. I understand that for data verification and quality control purposes regulatory authorities and/or members of the Wits Human Research Ethics Committee (Medical) may be allowed access to my personal data under conditions of strict confidentiality.

I understand that I may be contacted for a follow-up study.

I agree to participation in the study on the condition that:

1. I can withdraw voluntarily from the study at any time and that no adverse consequences will follow on withdrawal from the study.

2. I have the right not to answer any or all questions posed in the questionnaire.

3. The University of the Witwatersrand's Human Research Ethics Committee has approved the study protocol and procedures.

4. All results will be treated with the strictest confidentiality.

5. The study scientific team is committed to treating participants with respect.

6. I will receive a referral note to psychological services if I experience any psychological distress during the study.

I have read the information, or it has been read to me. I have had the opportunity to ask questions about it and my questions have been answered to my satisfaction. I consent voluntarily and understand that I have the right to withdraw my consent without this affecting the current research study or my medical care.

Print Name of Participant _____

Signature of Participant _____

Date _____

I have accurately read or witnessed the accurate reading of the consent form to the potential participant, and the individual has had the opportunity to ask questions. I confirm that the individual has given consent freely.

RESEARCH ASSISTANT:

Printed Name	Signature/Mark or Thumbprint	Date and Time

Copy provided to participant _____ (initialled by researcher)

WITNESS: (If applicable)

Printed Name	Signature/Mark or Thumbprint	Date and Time

Appendix B: Anthropometric measurements

Anthropometric measurements

	Remember to note the device ID for the stadiometer and scales you use. For each participant, take one measurement of height and one measurement of weight. Take two measurements of waist, hip and mid upper-arm circumference and take a third measurement if there is a difference of ≥ 1cm between the first two measurements.	
1.1 1.2	Device ID for stadiometer Device ID for scales	
1.3	Height 1	___ cm
	Height 2	___ cm
	Height 3	___ cm
1.4	Weight 1	___kg
1.5	Waist circumference 1	___cm
1.6	Waist circumference 2	___cm
1.7	Waist circumference 3	___cm
1.8	Hip circumference 1	___cm
1.9	Hip circumference 2	___cm
1.10	Hip circumference 3	___cm
1.11	Mid upper-arm circumference 1	___cm
1.12	Mid upper-arm circumference 2	___cm
1.13	Mid upper-arm circumference 3	___cm

Appendix C : Participants Socio-Demographics

SOCIO-DEMOGRAPHICS	
How old are you?	_____ years
What is your gender?	☐ Male ☐ Female
Study ID of young adult participant	
What is your relationship to the young adult participant?	☐ Parent ☐ Adult relative/sibling ☐ Grandparent ☐ Caregiver
What is your highest level of education?	☐ No formal schooling ☐ Primary school ☐ Some high school ☐ Completed high school ☐ Diploma/Higher Diploma ☐ Bachelor's degree ☐ Graduate (Masters/PhD)/professional degree
In the next few questions we are interested in your household. People are considered household members if they regularly share meals and live together and pool (part of) their monetary resources.	
How many adults (18 years and older) live in your household most of the time?	_____ Number of adults
How many children (<18 years) live in your household most of the time?	_____ Number of children/adolescents
Are there any children <16 years in the household NOT in school?	☐ Yes ☐ No
Have you ever had a child who was born alive but later died?	☐ Yes ☐ No
What type of main dwelling does your household live in?	☐ Free-standing house ☐ Bungalow/Garden cottage/"Wendy House" ☐ Flat/Apartment ☐ Maisonette/townhouse ☐ Thatch roof / clay house ☐ Shanty/shack ☐ Other (specify):_____
[Interviewer observe] Main material for the dwelling floor	☐ Natural (earth, sand, dung) ☐ Rudimentary (palm, bamboo, wood, cardboard ☐ Finished floor (carpet, laminate/wood planks, tiles, cement)

Household assets: Does your household have…? (Tick any that apply)	☐ Electricity ☐ Radio ☐ Refrigerator ☐ Television ☐ Landline telephone ☐ Mobile telephone ☐ Bicycle ☐ Motorbike / Scooter ☐ Car
What is the MAIN source of water for your household?	☐ Piped water (into dwelling or plot) ☐ Public tap/stand pipe ☐ Tubewell/borehole with pump ☐ Dug well ☐ Water from spring ☐ Rainwater collection ☐ Vendors (e.g tanker or cart) ☐ Surface water (e.g. river, stream, pond) ☐ Bottled water ☐ Other [specify] _____
Distance to primary water source: How long does it take to get to the water source, get water, and come back?	_____Hours; _____Minutes ☐ Our water is on Premises ☐ Don't know
What kind of toilet do members of your household usually use?	☐ Flush / pour flush toilet ☐ Pit latrine ☐ Composting toilet Bucket ☐ Hanging toilet/hanging latrine ☐ No facilities or bush or field ☐ Other (specify) _____
Do you share this toilet with other households?	☐ Yes ☐ No

What type of fuel does your household MAINLY use for cooking?	☐ Electricity ☐ Gas ☐ Kerosene ☐ Charcoal ☐ Wood ☐ Animal dung ☐ Liquid Propane Gas (LPG) ☐ Biogas
How does your young adult who is part of the study usually get to and from university/collage and or work? (select all that apply)	☐ Foot ☐ Car ☐ Bicycle ☐ Public bus ☐ School bus ☐ Train ☐ Taxi-bus (Matatu) ☐ Taxi- motorcycle (Boda boda) ☐ Private Motorcycle ☐ Tuk-tuk ☐ Other (specify):_____

Appendix D: Nutritional knowledge questionnaire

Section a: The first few items are about what advice you think experts are giving us.

	ITEMS	CHOICES
Do health experts recommend that people should be eating more, the same amount, or less of the following foods? (tick one box per food)	Fruit Food and drinks with added sugar Vegetables Fatty foods Processed red meat Wholegrains Salty foods Water	☐ More ☐ Same ☐ Less ☐ Not Sure ☐ More ☐ Same ☐ Less ☐ Not Sure ☐ More ☐ Same ☐ Less ☐ Not Sure ☐ More ☐ Same ☐ Less ☐ Not Sure ☐ More ☐ Same ☐ Less ☐ Not Sure ☐ More ☐ Same ☐ Less ☐ Not Sure ☐ More ☐ Same ☐ Less ☐ Not Sure ☐ More ☐ Same ☐ Less ☐ Not Sure
How many servings of fruit and vegetables per day do experts advise people to eat as a minimum? (One serving could be, for example, an apple or a handful of chopped carrots) (tick one)		☐ 2 per day ☐ 3 per day ☐ 4 per day ☐ 5 or more per day ☐ Not sure
Which of these types of fats do experts recommend that people should eat less of? (tick one box per food)	Unsaturated fats Trans fats Saturated fats	☐ Eat Less ☐ No recommendation ☐ Not Sure ☐ Eat Less ☐ No recommendation ☐ Not Sure ☐ Eat Less ☐ No recommendation ☐ Not Sure
Which types of dairy foods do experts say people should drink? (tick one)		☐ Full fat (e.g. full fat milk) ☐ Reduced fat (e.g. skimmed, semi- skimmed milk) ☐ Mixture of full fat and reduced fat ☐ Neither, dairy foods should be avoided ☐ Not sure

How many times per week do experts recommend that people eat oily fish (e.g. salmon and mackerel)? (tick one)		☐ 1-2 times per week ☐ 3-4 times per week ☐ Every day ☐ Not sure
How many times per week do experts recommend that people eat breakfast? (tick one)		☐ 3 times per week ☐ Every day ☐ 4 times per week ☐ Not sure
If a person has two glasses of fruit juice in a day, how many of their daily fruit and vegetable servings would this count as? (tick one)		☐ None ☐ 3 servings ☐ 1 serving ☐ Not sure ☐ 2 servings
Section b: Experts classify foods into groups. We are interested to see whether people are aware of food groups and the nutrients they contain.		
Do you think these foods and drinks are typically **high or low in added sugar**? (tick one box per food)	Diet cola drinks Natural yoghurt Ice cream Tomato ketchup Melon	☐ High ☐ Low ☐ Not sure ☐ High ☐ Low ☐ Not sure ☐ High ☐ Low ☐ Not sure ☐ High ☐ Low ☐ Not sure ☐ High ☐ Low ☐ Not sure
Do you think these foods are typically **high or low in salt**? (tick one box per food)	Breakfast cereals Frozen vegetables Bread Baked beans Red meat Canned soup	☐ High ☐ Low ☐ Not sure ☐ High ☐ Low ☐ Not sure ☐ High ☐ Low ☐ Not sure ☐ High ☐ Low ☐ Not sure ☐ High ☐ Low ☐ Not sure ☐ High ☐ Low ☐ Not sure
Do you think these foods are typically **high or low in fibre**? (tick one box per food)	Oats Bananas White rice Eggs Potatoes with skin Pasta	☐ High ☐ Low ☐ Not sure ☐ High ☐ Low ☐ Not sure ☐ High ☐ Low ☐ Not sure ☐ High ☐ Low ☐ Not sure ☐ High ☐ Low ☐ Not sure ☐ High ☐ Low ☐ Not sure

Do you think these foods are a **good source of protein**? (tick one box per food)	Poultry Cheese Fruit Baked beans Butter Nuts	☐ Good source ☐ Not a Good source ☐ Not sure ☐ Good source ☐ Not a Good source ☐ Not sure ☐ Good source ☐ Not a Good source ☐ Not sure ☐ Good source ☐ Not a Good source ☐ Not sure ☐ Good source ☐ Not a Good source ☐ Not sure ☐ Good source ☐ Not a Good source ☐ Not sure
Which of the following foods do experts count as **starchy foods**? (tick one box per food)	Cheese Pasta Potatoes Nuts Plantains	☐ Starchy food ☐ Not a Starchy food ☐ Not sure ☐ Starchy food ☐ Not a Starchy food ☐ Not sure ☐ Starchy food ☐ Not a Starchy food ☐ Not sure ☐ Starchy food ☐ Not a Starchy food ☐ Not sure ☐ Starchy food ☐ Not a Starchy food ☐ Not sure
Which is the **main type of fat** present in each of these foods? (tick one box per food)	Olive oil Butter Sunflower oil Eggs	☐ Polyunsaturated ☐ Monounsaturated ☐ Saturated ☐ Cholesterol ☐ Not sure ☐ Polyunsaturated ☐ Monounsaturated ☐ Saturated ☐ Cholesterol ☐ Not sure ☐ Polyunsaturated ☐ Monounsaturated ☐ Saturated ☐ Cholesterol ☐ Not sure ☐ Polyunsaturated ☐ Monounsaturated ☐ Saturated ☐ Cholesterol ☐ Not sure
Which of these foods has the **most trans-fat?** (tick one)		☐ Biscuits, cakes and pastries ☐ Fish ☐ Rapeseed oil ☐ Eggs ☐ Not sure

Compared to minimally processed foods, **processed foods** (e.g. foods that have been changed to increase their shelf life) are: (tick one)	☐ Higher in calories ☐ Higher in fibre ☐ Lower in salt ☐ Not sure
Section c: The next few items are about choosing foods	
If a person wanted to buy a yogurt at the supermarket, which would have the **least sugar/sweetener**? (tick one)	☐ 0% fat cherry yogurt ☐ Natural yogurt ☐ Creamy fruit yogurt ☐ Not sure
Which of the following cooking methods **requires fat to be added**? (tick one)	☐ Grilling ☐ Steaming ☐ Baking ☐ Sautéing ☐ Not sure
"Light" foods (or Diet foods) are always good options because they are low in calories. (tick one)	☐ Agree ☐ Disagree ☐ Not sure
Section d: This section is about health problems or diseases related to diet and weight management	
Which of these diseases is related to **how much sugar people eat**? (tick one)	☐ High blood pressure ☐ Tooth decay ☐ Anaemia ☐ Not sure
Which of the diseases is related to **how much salt (or sodium) people eat**? (tick one)	☐ Hypothyroidism ☐ Diabetes ☐ High blood pressure ☐ Not sure
Which of these options do experts recommend to **prevent diabetes**? (tick one)	☐ Eating less refined foods ☐ Drinking more fruit juice ☐ Eating more processed meat

		☐ Not sure
What of these options can help people to **maintain a healthy weight**? (answer each one)	Not eating while watching TV…….	Yes ☐ No ☐ Not sure ☐
	Reading food labels…….	Yes ☐ No ☐ Not sure ☐
	Taking nutritional supplements ……	Yes ☐ No ☐ Not sure ☐
	Monitoring their eating …….	Yes ☐ No ☐ Not sure ☐
	Monitoring their weight…….	Yes ☐ No ☐ Not sure ☐
	Grazing throughout the day …….	Yes ☐ No ☐ Not sure ☐
If someone has a **Body Mass Index (BMI) of 23kg/m²**, what would their weight status be? (tick one)	☐ Underweight ☐ Normal weight ☐ Overweight ☐ Obese ☐ Not sure	
If someone has a **Body Mass Index (BMI) of 31kg/m²**, what would their weight status be? (tick one)	☐ Underweight ☐ Normal weight ☐ Overweight ☐ Obese ☐ Not sure	

Appendix E: Food Frequency Questionnaire

How many times a week do you usually eat . . . ? (Please mark only one box for each line)	Never	Less than once a week	Once a week	2-4 times a week	5-6 times a week	Once a day, every day	Every day, more than once
Fruits	☐	☐	☐	☐	☐	☐	☐
Vegetables	☐	☐	☐	☐	☐	☐	☐
Sweets (candy/chocolate)	☐	☐	☐	☐	☐	☐	☐
Regular cola or soft drinks that contain sugar	☐	☐	☐	☐	☐	☐	☐
Cake, pastries & pies or donuts, samosa	☐	☐	☐	☐	☐	☐	☐
Diet cola or sugar-free soft drinks	☐	☐	☐	☐	☐	☐	☐
Potato chips (crisps)	☐	☐	☐	☐	☐	☐	☐
French fries (chips)	☐	☐	☐	☐	☐	☐	☐
Dark green vegetables (broccoli, spinach, etc.)	☐	☐	☐	☐	☐	☐	☐
Orange vegetables (carrots, butternut, sweet potato, etc.)	☐	☐	☐	☐	☐	☐	☐
Fruit juice	☐	☐	☐	☐	☐	☐	☐
Low fat milk (1%,2%, skim)	☐	☐	☐	☐	☐	☐	☐
Full-cream milk	☐	☐	☐	☐	☐	☐	☐
Cheese	☐	☐	☐	☐	☐	☐	☐
Other milk products (yogurt, chocolate milk, pudding, etc.)	☐	☐	☐	☐	☐	☐	☐
Whole grain bread or cereal (oatmeal, muesli, pap, etc.)	☐	☐	☐	☐	☐	☐	☐
Meat alternatives (beans, lentils, soya mince, tofu, eggs, peanut butter, etc.)	☐	☐	☐	☐	☐	☐	☐
Energy drinks (Red Bull, Play, Dragon, Monster.)	☐	☐	☐	☐	☐	☐	☐
Sports drinks (Gatorade, Powerade, etc.)	☐	☐	☐	☐	☐	☐	☐
Fish	☐	☐	☐	☐	☐	☐	☐
Ice cream	☐	☐	☐	☐	☐	☐	☐
Fried food such as chicken wings, chicken fingers, etc.	☐	☐	☐	☐	☐	☐	☐
Fast foods such as pizza, hamburgers, etc.	☐	☐	☐	☐	☐	☐	☐

How many times a week do you usually eat the following food items **while watching television**?

	Never	Less than once a week	Once a week	2-4 times a week	5-6 times a week	Once a day, every day	Every day, more than once
Potato chips, crisps or peanuts/	☐	☐	☐	☐	☐	☐	☐
Fried food such as chicken wings, chicken fingers, etc.	☐	☐	☐	☐	☐	☐	☐
Cookies, biscuits, chocolate or candy bars	☐	☐	☐	☐	☐	☐	☐
Ice cream	☐	☐	☐	☐	☐	☐	☐
Fast foods such as pizza, hamburgers, kota.	☐	☐	☐	☐	☐	☐	☐

On how many days in a week do you usually have **breakfast** (more than a glass of milk or fruit juice)?
Mark one box for weekdays and one box for weekend.

Weekdays	**Weekend**
☐ I never have breakfast on weekdays	I never have breakfast on the weekend
☐ One day	I usually have breakfast on only one day of
☐ Two days	the weekend (Saturday OR Sunday)
☐ Three days	I usually have breakfast on both weekend
☐ Four days	days (Saturday AND Sunday)
☐ Five days	

Appendix F: Physical Activity Questionnaire

Global Diet and Physical Activity Study
GLOBAL PHYSICAL ACTIVITY QUESTIONNAIRE (GPAQ) 2013

ID: _____

Interviewer's name: _____

Interview date: _____

Physical Activity

Next I am going to ask you about the time you spend doing different types of physical activity in a typical week. Please answer these questions even if you do not consider yourself to be a physically active person.

Think first about the time you spend doing work. Think of work as the things that you have to do such as paid or unpaid work, study/training, household chores, harvesting food/crops, fishing or hunting for food, seeking employment. *[Insert other examples if needed]*. In answering the following questions 'vigorous-intensity activities' are activities that require hard physical effort and cause large increases in breathing or heart rate, 'moderate-intensity activities' are activities that require moderate physical effort and cause small increases in breathing or heart rate.

Questions		Response	Code
Activity at work			
1	Does your work involve vigorous-intensity activity that causes large increases in breathing or heart rate like *[carrying or lifting heavy loads, digging or construction work]* for at least 10 minutes continuously? *[INSERT EXAMPLES] (USE SHOWCARD)*	Yes 1 No 2 *If No, go to P 4*	P1
2	In a typical week, on how many days do you do vigorous-intensity activities as part of your work?	Number of days ⌊__⌋	P2
3	How much time do you spend doing vigorous-intensity activities at work on a typical day?	Hours : minutes ⌊__⌋⌊__⌋ : ⌊__⌋⌊__⌋ (hrs : mins)	P3 (a-b)
4	Does your work involve moderate-intensity activity that causes small increases in breathing or heart rate such as brisk walking *[or carrying light loads]* for at least 10 minutes continuously? *[INSERT EXAMPLES] (USE SHOWCARD)*	Yes 1 No 2 *If No, go to P 7*	P4
5	In a typical week, on how many days do you do moderate-intensity activities as part of your work?	Number of days ⌊__⌋	P5
6	How much time do you spend doing moderate-intensity activities at work on a typical day?	Hours : minutes ⌊__⌋⌊__⌋ : ⌊__⌋⌊__⌋ (hrs : mins)	P6 (a-b)
Travel to and from places			
The next questions exclude the physical activities at work that you have already mentioned. Now I would like to ask you about the usual way you travel to and from places. For example to work, for shopping, to market, to place of worship. [insert other examples if needed]			
7	Do you walk or use a bicycle (pedal cycle) for at least 10 minutes continuously to get to and from places?	Yes 1 No 2 *If No, go to P 10*	P7
8	In a typical week, on how many days do you walk or bicycle for at least 10 minutes continuously to get to and from places?	Number of days ⌊__⌋	P8
9	How much time do you spend walking or bicycling for travel on a typical day?	Hours : minutes ⌊__⌋⌊__⌋ : ⌊__⌋⌊__⌋ (hrs : mins)	P9 (a-b)

Physical Activity (recreational activities) contd.			
Questions		**Response**	**Code**
13	Do you do any moderate-intensity sports, fitness or recreational (*leisure*) activities that causes a small increase in breathing or heart rate such as brisk walking.(*cycling, swimming, volleyball*)for at least 10 minutes continuously? *[INSERT EXAMPLES] (USE SHOWCARD)*	Yes 1 No 2 *If No, go to P16*	P13
14	In a typical week, on how many days do you do moderate-intensity sports, fitness or recreational (*leisure*) activities?	Number of days ⌊__⌋	P14
15	How much time do you spend doing moderate-intensity sports, fitness or recreational (*leisure*) activities on a typical day?	Hours : minutes ⌊__⌋ : ⌊__⌋ hrs mins	P15 (a-b)

Appendix G: Paper 2 Information sheet and Consent

INFORMATION SHEET
Global Diet and Activity Research
Citizen Science sub-study (Focus Group Discussion)

Hello, my name is Gudani Mukoma and I am a researcher at the SAMRC/Wits Developmental Pathways for Health Research Unit (DPHRU) at the University of the Witwatersrand. I together with other researchers would like to invite you to participate in a research project.

Before you agree to participate, it is important that you understand the purpose of the study, the study procedures, benefits, and risks as well as your right to withdraw from the study at any time. If you have any questions, do not hesitate to ask me. You should not agree to take part unless you are satisfied with all the procedures involved. If you decide to take part in this study, you will be asked to sign this document to confirm that you understand the study. You will also be given a copy to keep.

Where will the research be conducted?
All the research will be undertaken at the SAMRC/Wits Developmental Pathways for Health Research Unit, which is based at Chris Hani Baragwanath Hospital in Soweto.

What is the purpose of the research?
The aim of this study is to capture the breadth of backgrounds understand the lived experiences of food and physical activity of people of your age.

Participant selection
We are inviting older adolescents from Soweto who have previously participated in a study titled: Levers for intervention for Diet and Physical Activity in Older Adolescents who have transitioned out of high school at varying socio-ecological levels to participate.

Do I have to take part?
Your participation is voluntary. We would like you to participate in this study as we believe that you can make an important contribution to the research. If you decide to take part you are still free to withdraw at any time.

What would I be asked to do if I took part?
If you are happy to participate in the research we will ask you to read this information sheet and sign the consent form. You will be trained as a "Citizen Scientist" and will be asked to record (either by photograph or by audio recording) the food, drink and physical activity environments you are exposed to on a daily basis. You will also be asked to complete a short questionnaire. You will then be invited to take part in a small discussion group of 6-8 people to discuss these issues so that we can better understand your thoughts about your environment and how it can be changed to encourage healthy eating behaviour and encourage fun and enjoyable physical activity..

Please note that these discussions will be audio recorded so that we can capture your insights in your own words. Therefore, your information and feelings shared will not be anonymous to the group (we will only use first names and not surnames); however, the tapes will only be heard by the researchers for the purposes of this study, and will be kept in the strictest confidence. The recordings will be stored on the researcher's computer (password protected) and destroyed after not longer than 6 years following the completion of the project and depending on the publication of results. Direct quotes from you may be used in a published paper; however, your name and other identifying information will be kept anonymous.

We expect the focus group discussion to take approximately 45-90 minutes of your time.

We may call you after the focus group discussion to follow up on any of the questions.

Risks
There are no risks for taking part in this study.

Benefits
There are no direct benefits to participating in this research project.

Transport costs
We will reimburse you R150 for transportation costs to and from the research unit at the Chris Hani Baragwanath hospital.

What happens to the data collected?
All information you provide to us will be kept confidential. Only members of the research team will have access to it. Information gained during the research will be used as part of a larger sample, and will remain anonymous. The outcomes of the research will be available in one or more of the following sources: scientific papers in peer reviewed academic journals, presentations at a regional conference, local seminars.

Ethical approval
This study protocol has been submitted to the University of the Witwatersrand Human Research Ethics Committee (HREC) and received written approval.

Who do I contact if I have any questions about the study?
If you have any questions or you experience any problems during or after the sessions, please contact Professor Shane Norris or a representative of the Human Research Ethics Committee.

Gudani Mukoma
Principal Investigator
MRC/Wits Developmental Pathways for Health Research Unit
Chris Hani Baragwanath Hospital
Soweto Johannesburg
Tel: 011-9331122
Email: gudani.mukoma@wits.ac.za

Human Research Ethics Committee contact details:
If you have any concern over the way the study is being conducted, please contact the Chairperson of this Committee who is Professor Clement Penny, who may be contacted on telephone number 011 717 2301, or by e-mail on Clement.Penny@wits.ac.za. The telephone numbers for the Committee secretariat are 011 717 2700/1234 and the e-mail addresses are Zanele.Ndlovu@wits.ac.za and Rhulani.Mukansi@wits.ac.za

CONSENT SHEET

"I, _____, hereby give consent to participate in this research focus group to be conducted by SAMRC/Wits DPHRU, within the Department of Paediatrics at the University of Witwatersrand.

I understand that the study will involve answering questions by means of a discussion within a focus group. The purpose and all the details of this study have been explained to me.

I have read and have had explained to me the procedure described. I have had an opportunity to ask questions and my questions have been answered in a satisfactory way.

I understand that all the information collected during the study will be treated with the strictest confidentiality and will only be used for scientific research purposes. All records will be kept in a locked room and in a secure computer database in the research unit. My name will not be used in any publication of the results. I understand that for data verification and quality control purposes regulatory authorities and/or members of the Wits Human Research Ethics Committee (Medical) may be allowed access to my personal data under conditions of strict confidentiality.

I understand that I may be contacted for a follow-up study.

I agree to participation in the study on the condition that:

1. I can withdraw voluntarily from the study at any time and that no adverse consequences will follow on withdrawal from the study.

2. The study scientific team are committed to treating participants with respect and I have the right not to answer any or all questions posed in the discussion.

3. The University of the Witwatersrand's Human Research Ethics Committee has approved the study protocol and procedure.

4. Only group results, and not my individual results, will be published in scientific journals and in the media.

5. I understand that the interview will be recorded and that the tape will be destroyed after 6 years without publication or 2 years after publication.

6. I understand that the information that I give and all results will be treated in the strictest confidentiality and that my name will not be used when the interviews are typed up.

7. I will receive a referral note to psychological services if I experience any psychological distress during the focus group discussion.

◯ Yes, I give my permission for the interview to be recorded

◯ No, I do not give my permission for the interview to be recorded

PARTICIPANT:

Printed Name	**Signature / Mark or Thumbprint**	**Date and Time**

RESEARCH ASSISTANT:

Printed Name	**Signature**	**Date and Time**

WITNESS:

Printed Name	**Signature**	**Date and Time**

Appendix H: Paper 2 Focus Group Interview Guide

Focus Group Discussion Guide: Citizen Scientist's barriers and solutions to healthy eating and physical activity.

a. How do you define health? What makes you healthy?

b. How do you define healthy living? What makes it difficult to be healthy?

c. What do you understand about nutrition and physical activity?

d. What key areas do you think should be prioritized to address challenges of or improve nutrition? What solutions or interventions do you suggest solving these challenges?

e. How is the way we eat related to our health? How important is it? Can you have a bad diet and still be healthy?

f. What key areas do you think should be prioritized to address challenges of insufficient physical activity? What solutions or interventions do you suggest solving these challenges?

g. How do you think physical activity is related to health? How important is it? Can you be physically inactive and still be healthy?

h. What do you understand by obesity? Is it a problem in your community?

i. What are the causes of obesity? What are the risks associated with obesity?

j. Is there any relationship between nutrition, physical activity, and obesity?

k. What can be done to address the prevalence of obesity and improve health in your community?

l. Are there any programs available that you know that focus on improving health in your community? Give some examples and what they do.

m. Who do you think should be involved in finding solutions to address challenges of nutrition, physical activity and obesity in your community? Why?

Appendix I : Paper 3 Information Sheets and consent

Information Sheet: Adolescents (16-21 years)

COVID-19: exploring messaging and support for young people – Virtual Focus group Discussion with Urban Black Adolescents living in Soweto

Hello, my name is Gudani Mukoma, and I am a Researcher and Project Coordinator at the Chris Hani Baragwanath Hospital for the SAMRC/Wits Developmental Pathways for Health Research Unit (DPHRU) from the University of the Witwatersrand.

Together with other researchers are conducting a research study to look into the views and response of adolescents in Soweto to the COVID-19 pandemic. Your knowledge on this topic is required to help us understand what you know about the COVID-19 pandemic and how best to support you. Before you decide whether to participate, we would like you to understand why the research is being done, and what it would involve for you. We will also be asking your parent or guardian if it would be okay for you to take part, but even if he or she says "yes," you do not have to take part.

What is involved in the study?
The study will be organized at our offices in Chris Hani Baragwanath Hospital, SAMRC/Wits Developmental Pathways for Health Research Unit (DPHRU). Participation will be via an online video conferencing platform for the next 6 months. If you agree to take part in the study, you will be asked to participate in a virtual focus group discussion. This is just a name for a small group of adolescents of your own age and sex who connect together to talk about the COVID-19 pandemic. Only one online discussion will be conducted with you and your group per month.

Study procedure
Focus Group Discussion
6-8 adolescents who are 16-17 years of age will take part in the discussion. There will be two research assistants who will conduct the virtual focus group discussion, one asking questions and the other taking notes, but the idea of the discussion is for you to talk with the other group members. The research assistants will ask you to share what you think about adhering to government advice in response to the COVID-19 pandemic; How the pandemic is affecting you and other young people's lives mental health and well-being and eating habits; and physical activity behaviours and how young people can be supported to eat well and keep active during the pandemic. You do not need to participate in any discussion that makes you feel uncomfortable. The discussion will take between 60 and 90 minutes to complete.

Recording of the focus group:
The questions of the discussion will be asked in English and the research assistants will be available so that you can discuss in the language(s) that are most comfortable to you. With your permission, the discussion will be **audio-recorded** by an online video conferencing platform to ensure that we do not miss anything that is said.

Possible risks:
For focus group discussions, we cannot guarantee privacy. Although we will ask those taking part not to talk about the discussion afterwards, there is no way we can control their actions after the discussions. You should remember this when deciding what to say during the discussion. What we promise is that we will treat any information you share with us as private.

Possible benefits:

You will not benefit directly from taking part in this study. However, the information you provide may assist us in finding ways to message and support young people during the COVID-19 pandemic.

Taking part in the research will involve no cost you. You will receive a R150 airtime voucher to purchase a data bundle for you to connect via video conferencing for each discussion.

Voluntary participation in research:

You have the right to agree or refuse to take part in this research. If you decide to take part and later change your mind, you are free to leave from the study at any time. Nothing will happen to you.

Records of your participation in this research:

You have the right to privacy. All the information we gather will be put together so that information from any one of you will remain a secret, and none of you will be identified in any report or publication about this study. The results of this research may appear in scientific publications without identifying you in any way.

Your questions:

If you have any questions at any time please you contact me on the details below

Mr Gudani Mukoma
Telephone Number: 011 933 1120
E-mail: Gudani.Mukoma@wits.ac.za

This study has been approved by the Human Research Ethics Committee (Medical) of the University of the Witwatersrand, Johannesburg. It is the job of this Committee to look after the way people like yourself who take part in research studies like this one are treated. If you feel you have not been treated fairly, or are not happy with the answers you are given by Mr Mukoma, please contact the Chairperson of this Committee who is Professor Clement Penny: he may be contacted on telephone number 011 717 2301, or by e-mail on Clement.Penny@wits.ac.za. The telephone numbers for the Committee secretariat are 011 717 2700/1234 and the e-mail addresses are Zanele.Ndlovu@wits.ac.za and Rhulani.Mukansi@wits.ac.za

Thank you for reading this Study Information Sheet.

Consent (18-21 years) - COVID-19: Exploring Messaging and Support for Young People – Virtual Focus Group Discussion with Urban Black South Africans living in Soweto

Consent to take part in the study:

"I, _____, hereby give my agreement to take part in this research study to be conducted at DPHRU, Chris Hani Baragwanath Hospital.

I understand that the study will involve talking with a small group of adolescents of my own age about the COVID-19 pandemic via an online video conferencing platform. The aim and all the details of this study have been explained to me.

I have read and have had explained to me the process described. I have had an opportunity to ask questions and my questions have been answered in a satisfactory way.

I understand that all the information collected during the study will be treated with the strictest privacy and will only be used for scientific research goals. All records will be kept in a locked room and in a secure computer program in the research unit. My name will not be used in any publication of the results. I understand that it is possible, but very unlikely, that my personal information might be looked at by the Human Research Ethics Committee (Medical) of the University of the Witwatersrand (often referred to as "Wits").

I understand that I may be contacted for a follow-up study.

I agree to participation in the study on the condition that:

1. I can withdraw voluntarily from the study at any time without anything happening to me

2. I have the right not to answer any or all questions asked in the interview.

3. The University of the Witwatersrand's Human Research Ethics Committee (Medical) has approved everything about the study.

4. All results will be treated with the strictest privacy.

5. Only group results, and not my individual results, will be ever be made known to anyone else.

6. The study scientific team is committed to treating all those taking part with respect and privacy and I can talk to a trained nurse if I get upset by anything which happens during the study.

7. I agree that my answers may be recorded. This recording will be erased after not longer than 6 years.

   Yes/No (please score out the answer you do not agree with)

I have read the information, or it has been read to me. I have had the opportunity to ask questions about it and my questions have been answered to my satisfaction. I agree voluntarily to take part and understand that I have the right to withdraw my consent at any time

Consent

Print Name of Participant _____

Signature of Participant _____

Date _____

I have accurately read or witnessed the accurate reading of the consent form to the potential participant, and the individual has had the opportunity to ask questions. I confirm that the individual has given consent freely.

RESEARCH ASSISTANT:

Printed Name	Signature/Mark or Thumbprint	Date and Time

Appendix J: Virtual FGD guide - COVID-19: Exploring Messaging and Support for Young People

FGD Questions:

1. What do you know about the coronavirus pandemic and who has told you this? Where did you hear about it?
2. What is going on for you right now? How are you spending your time? What has changed for you ever since the lockdown was implemented? Do you think the lockdown was necessary?
3. What do you think about what you've heard and what you are being told to do?
4. Do you have any fear of contracting the Corona virus? What worries you the most?
5. Do you think the current situation (Covid-19 pandemic) has potential effects on one's mental health? What kind of mental health problems can one experience and why?
6. How do you think people in your generation are dealing with this situation?
7. How has the pandemic and stages of lockdown impacted your family/household? How has the impact affected livelihoods? How has the impact affected household food security?
8. What do you think about the government's response to the pandemic? Are you happy with how they are managing the situation? What do you think about the R350 social grant that the government is offering to the unemployed? Is any member of your household accessing this grant?
9. Do you think the different stages of lockdown are working? What changes would you recommend?
10. How has the pandemic affected you in terms of schooling, behaviours (physical activity, sedentary, sleep), diet, health, stress?
11. What do you think of the department of education's response to schooling during the lockdown? Do you think online learning is working for you and why?
12. What do you think we could do to help young and vulnerable people to stay safe and follow government advice? What would the messages from the government be to make young people follow the guidance? Where should these messages be placed?
13. What could young people do that would help and how do we involve young people in keeping other young people safe?
14. What solutions/interventions in your community could help with families impacted by the pandemic?
15. What do you think of the future amid what is currently happening?
16. What would you recommend to researchers studying young people?

Appendix K: Paper 4 Information and Consent

Dietary practices in black South African (SA) young men and women living in Soweto

Invitation
Hello, my name is Gudani Mukoma, and I am a Researcher and Project Coordinator at the MRC/Wits Developmental Pathways for Health Research Unit (DPHRU) from the University of the Witwatersrand.

I would like to invite you to participate in the research study entitled, Dietary practices in black South African men and women. Before, agreeing to participate, it is important that you understand the purpose of the study, the study procedures, benefits, and risks as well as your right to withdraw from the study at any time. If you have any questions, do not hesitate to ask me. You should not agree to take part unless you are satisfied with all the procedures involved. If you decide to take part in this study, you will be asked to sign this document to confirm that you understand the study. You will also be given a copy to keep.

Why is the study being done?
The study aims to understand dietary practices of young men and women.

Who can participate?
Participants of the Birth to Twenty Cohort Study are eligible for this follow-up study

What will happen if you decide to take part in the study?
If you meet the criteria and decide to take part in the study, you will be required to complete three interview sessions (baseline, at 6months, and again at 12 months). These sessions will be completed at DPHRU at Chris Hani Baragwanath Academic Hospital in Soweto.

You are under no obligation to take part in the study and are not required to give a reason if you do not wish to participate. If you decide to take part in the study, you are free to withdraw at any time and without giving a reason and without prejudice. If you decide to withdraw from the study, we will discuss with you what will happen to any information you have provided. If the incomplete information can usefully contribute to the study, we will ask your permission to store it and use it in our analysis. Alternatively, on your request, all your information will be destroyed.

For session 1 and 3:
You will be requested to complete questionnaires (food and beverage frequency) in private assisted by a trained research assistant who will guide you through the process and questions. These two sessions will take no longer than one and a half hours. Further details of these procedures are provided below:

Food frequency questionnaire (FFQ)
You will also be asked to fill in a food frequency questionnaire to measure your usual dietary intake (what you normally eat). This questionnaire will give us a sense of what and how much you have eaten over the last week. In addition, we will ask you a few questions about your food security, in other words, your access to food and if you or your family ever experience periods of hunger.

Beverage frequency questionnaire (BFQ)
You will also be asked to fill in a beverage frequency questionnaire to measure your usual intake (what you normally drink). This questionnaire will give us a sense of what and how much you have consumed over the last week.
For session 2:

You will be requested to complete only the beverage frequency questionnaire by interview. These sessions will take no longer than half an hour.

What are the risks and discomforts of this study?
There are no risks or discomforts associated with the administration of the questionnaires. Strict confidentiality of results will be maintained. Your name will be removed from all data, and you will be assigned a number, which will be used to identify data relating to you. All records will be kept in a locked room and in a secure computer database in the research unit. Your name will not be used in any publication of the results. If you experience any psychological distress while completing the questions or wish to raise any concerns you will be referred to Sr Thoko who a professional nurse with extensive counseling experience and she is will assist you.

Are there any benefits to you for being in the study?
There are no direct benefits to you for being part of the study.

Will you receive reimbursement for transport?
You will receive R150 to cover transport costs to DPHRU for each of the two testing sessions. The transport money will be paid to you at the end of each session.

Who will see the information that is collected about you during the study?
Strict confidentiality of results will be maintained. Your name will be removed from all data, and you will be assigned a number, which will be used to identify data relating to you. All records will be kept in a locked room and in a secure computer database in the research unit. Your name will not be used in any publication of the results.

Who do I contact if I have any questions about the study?
If you have any questions or experience any problems during or after the sessions, please contact Professor Shane Norris or a representative of the Human Research Ethics Committee.

Professor Shane Norris (Ph.D.)
Principal Investigator
MRC/Wits Developmental Pathways for Health Research Unit
Chris Hani Baragwanath Hospital
Soweto Johannesburg
Tel: 011-9331122
Email: shane.norris@wits.ac.za

Human Research Ethics Committee contact details:
Prof P Cleaton-Jones, Tel 011 717 2301, email peter.cleaton-jones1@wits.ac.za or Ms. Zanele Ndlovu/ Mr. Rhulani Mkansi/ Mr. Lebo Moeng Administrative Officers 011 717 2700/2656/1234/1252 zanele.ndlovu@wits.ac.za; Rhulani.mkansi@wits.ac.za; and Lebo.moeng@wits.ac.za

Consent to participate in the study:
"I, _____, hereby give consent to participate in this research trial to be conducted by DPHRU, within the Department of Pediatrics at the University of Witwatersrand.

I understand that the study will involve completion of questionnaires by interview. The purpose and all the details of this study have been explained to me.

I have read and have had explained to me the procedures described. I have had an opportunity to ask questions and my questions have been answered in a satisfactory way.

I understand that all the information collected during the study will be treated with the strictest confidentiality and will only be used for scientific research purposes. All records will be kept in a locked room and in a secure computer database in the research unit. My name will not be used in any publication of the results. I understand that for data verification and quality control purposes regulatory authorities and/or members of the Wits Human Research Ethics Committee (Medical) may be allowed access to my personal data under conditions of strict confidentiality.

I understand that I may be contacted for a follow-up study.

I agree to participation in the study on the condition that:

1. I can withdraw voluntarily from the study at any time and that no adverse consequences will follow on withdrawal from the study.

2. I have the right not to answer any or all questions posed in the questionnaire.

3. The University of the Witwatersrand's Human Research Ethics Committee has approved the study protocol and procedures.

4. All results will be treated with the strictest confidentiality.

5. Only group results, and not my individual results, will be published in scientific journals and in the media.

6. The study scientific team are committed to treating participants with respect and privacy through interviews conducted in private and follow-up counseling available on request.

7. I will receive a referral note to psychological services if I experience any psychological distress during the study.

I have read the information, or it has been read to me. I have had the opportunity to ask questions about it and my questions have been answered to my satisfaction. I consent voluntarily and understand that I have the right to withdraw my consent without this affecting the current research study or my medical care.

Print Name of Participant _____

Signature of Participant _____

Date _____

PARTICIPANT INFORMATION SHEET

Adolescents

Invitation

Hello, my name is Gudani Mukoma, and I am a Researcher and Project Coordinator at the MRC/Wits Developmental Pathways for Health Research Unit (DPHRU) from the University of the Witwatersrand.

I would like to invite you to participate in the research study entitled, Dietary practices in South African adolescent boys and girls. Before, agreeing to participate, it is important that you understand the purpose of the study, the study procedures, benefits, and risks as well as your right to withdraw from the study at any time. If you have any questions, do not hesitate to ask me. You should not agree to take part unless you are satisfied with all the procedures involved. If you decide to take part in this study, you will be asked to sign this document to confirm that you understand the study. You will also be given a copy to keep.

We will need both you and your parent/caregiver agreement to participate in this study.

Why is the study being done?

The study aims to understand dietary practices of adolescent boys and girls.

Who can participate?

We will be selecting a convenient sample of adolescents living in Soweto (13 to 17 years of age).

What will happen if you decide to take part in the study?

If you decide to take part in the study, you will be required to complete three interview sessions (baseline, at 6months, and again at 12 months). These sessions will be completed at DPHRU at Chris Hani Baragwanath Academic Hospital in Soweto. As you are under the age of 18 years, we will ask one of your parents/caregivers to accompany you to the research centre but the interview with a trained research assistant will be conducted in private.

You are under no obligation to take part in the study and are not required to give a reason if you do not wish to participate. If you decide to take part in the study, you are free to withdraw at any time and without giving a reason and without prejudice. If you decide to withdraw from the study, we will discuss with you what will happen to any information that you have provided. If the incomplete information can usefully contribute to the study, we will ask your permission to use the data in our analysis. Alternatively, on your request, all your information will be destroyed.

For session 1 and 3:
You will be requested to complete questionnaires (information on your family and household; socio-demographic; food and beverage frequency) with a trained interviewer, and your height and weight will be measured. Sessions 1 and 3 will take no longer than one and a half hours. Further details of these procedures are provided below:

Demographic and socioeconomic status

You will be asked questions about your family and of your household (e.g., who you live with, does your household have a fridge, car, computer, etc).

Food frequency questionnaire (FFQ)

You will also be asked to fill in a food frequency questionnaire to measure your usual dietary intake (what you normally eat). This questionnaire will give us a sense of what and how much you have eaten over the last week. In addition, we will ask you a few questions about your food security, in other words, your access to food and if you or your family ever experience periods of hunger.

Beverage Frequency Questionnaire (BFQ)

You will also be asked to fill in a beverage frequency questionnaire to measure your usual intake (what you normally drink). This questionnaire will give us a sense of what and how much you have consumed over the last week

Height and weight measurements

We will determine your height by you standing next to a height board with no shoes on and we will ask you to stand on an electronic scale to determine your weight.

For session 2:

You will be requested to complete only the beverage frequency questionnaire by interview. These sessions will take no longer than half an hour.

What are the risks and discomforts of this study?

There are no risks or discomforts associated with the administration of the questionnaires. Strict confidentiality of results will be maintained. Your name will be removed from all data, and you will be assigned a number, which will be used to identify data relating to you. All records will be kept in a locked room and in a secure computer database in the research unit. Your name will not be used in any publication of the results. If you experience any psychological distress while completing the questions or wish to raise any concerns you will be referred to Sr Thoko who a professional nurse with extensive counseling experience and she is will assist you.

Are there any benefits to you for being in the study?

There are no direct benefits to you for being part of the study.

Will you receive reimbursement for transport?

You and your caregiver will each receive R150 each to cover transport costs to DPHRU for each of the two testing sessions. The transport money will be paid to you at the end of each session.

Who will see the information that is collected about you during the study?

Strict confidentiality of results will be maintained. Your name will be removed from all data, and you will be assigned a number, which will be used to identify data relating to you. All records will be kept in a locked room and in a secure computer database in the research unit. Your name will not be used in any publication of the results.

Who do I contact if I have any questions about the study?

If you have any questions or experience any problems during or after the sessions, please contact Professor Shane Norris or a representative of the Human Research Ethics Committee.

Professor Shane Norris (Ph.D.)
Principal Investigator
MRC/Wits Developmental Pathways for Health Research Unit
Chris Hani Baragwanath Hospital
Soweto Johannesburg
Tel: 011-9331122
Email: shane.norris@wits.ac.za

Human Research Ethics Committee contact details:
Prof P Cleaton-Jones, Tel 011 717 2301, email peter.cleaton-jones1@wits.ac.za or Ms. Zanele Ndlovu/ Mr. Rhulani Mkansi/ Mr. Lebo Moeng Administrative Officers 011 717 2700/2656/1234/1252 zanele.ndlovu@wits.ac.za; Rhulani.mkansi@wits.ac.za; and Lebo.moeng@wits.ac.za

Assent to participate in the study:

"I, _____, hereby give ascent to participate in this research study to be conducted by DPHRU, within the Department of Pediatrics at the University of Witwatersrand.

I understand that the study will involve completion of questionnaires by interview. The purpose and all the details of this study have been explained to me.

I have read and have had explained to me the procedures described. I have had an opportunity to ask questions and my questions have been answered in a satisfactory way.

I understand that all the information collected during the study will be treated with the strictest confidentiality and will only be used for scientific research purposes. All records will be kept in a locked room and in a secure computer database in the research unit. My name will not be used in any publication of the results. I understand that for data verification and quality control purposes regulatory authorities and/or members of the Wits Human Research Ethics Committee (Medical) may be allowed access to my personal data under conditions of strict confidentiality.

I understand that I may be contacted for a follow-up study.

I agree to participation in the study on the condition that:

7. I can withdraw voluntarily from the study at any time and that no adverse consequences will follow on withdrawal from the study.

8. I have the right not to answer any or all questions posed in the questionnaire.

9. The University of the Witwatersrand's Human Research Ethics Committee has approved the study protocol and procedures.

10. All results will be treated with the strictest confidentiality.

11. Only group results, and not my individual results, will be published in scientific journals and in the media.

12. The study scientific team is committed to treating participants with respect and privacy through interviews conducted in private and follow-up counseling available on request.

13. I will receive a referral note to psychological services if I experience any psychological distress during the study.

I have read the information, or it has been read to me. I have had the opportunity to ask questions about it and my questions have been answered to my satisfaction. I consent voluntarily and understand that I have the right to withdraw my consent without this affecting the current research study or my medical care.

Assent

Print Name of Participant _____

Signature of Participant _____

Date _____

Appendix M: Quantitative Food Frequency Questionnaire

F V

FOOD FREQUENCY QUESTIONNAIRE (FFQ)

DATE: **Day** ☐☐ **Month** ☐☐ **Year** ☐☐☐☐

☐☐☐☐☐☐☐

BTT NUMBER: **RA Name:**_____

Food habits

1. Are you on a special diet that has been prescribed for you e.g. by a doctor or one that you have adopted from someone e.g. a TV star/magazine?

YES	1
NO	0

2. If NO, go to question 4.
If YES, describe what kind of diet you are on and where you got the diet from?

_____

3. How long have you been on that diet?_____months/years.

4. Do you currently take any vitamin and mineral supplements?

YES	1
NO	0

IF YES, what do you take?

	Name of product	Amount/day (or how many tablets)
Vitamins/vitamins and minerals		
Tonics		
Vitamin D		
Calcium		

Body building preparations		
Dietary fibre supplement		
Other: specify		

5. Which meals do you skip almost on a daily basis?

Breakfast	1
Lunch	2
Evening meal	3
None	4

6. Is salt added to your food while it is being cooked?

Always	1
Sometimes	2
Never	3
Don't know	4

7. Do you add salt to your food before you eat it?

YES	1
NO	0

8. If yes, how much salt do you add to your food each day?

¼ teaspoon	1
½ teaspoon	2
¾ teaspoon	3
1 teaspoon	4
Other specify:	5

9. Do you add Aromat to your food before you eat it?

YES	1
NO	0

10. If yes, how much Aromat do you add to your food each day?

¼ teaspoon	1
½ teaspoon	2
¾ teaspoon	3
1 teaspoon	4
Other specify:	5

11. There are some factors which influence the choice of foods we eat. Which of the following statements are true for you?

	Strongly agree	Agree	Disagree	Strongly Disagree

I choose to eat certain foods because they taste good	1	2	3	4
The food I eat depends on whether it is expensive	1	2	3	4
I choose to eat certain foods because it looks good	1	2	3	4
The food I choose to eat differs according to my mood (i.e. happy/sad)	1	2	3	4
My hunger level determines what type of food I eat.	1	2	3	4
I choose foods which are not time consuming to prepare	1	2	3	4
I consider whether a food is good for my health before eating the food.	1	2	3	4

you ever eat outside the home e.g. at fast food shops such as Nandos, KFC and Steers?

YES	1
NO	0

13. If YES, in an average month how often do you eat at the following places?

	Frequency of visits		
	Times/week	Times/month	Rarely/never
Nandos			
Spur			
Macdonalds			
Steers			
KFC			
Chicken Licken			
Debonaire's Pizza			
Romans			
Anat			
Wimpy			
Something fishy			
Fontana			
Chinese takeaway			
Other restaurants/takeaways			
(Quarters from tuck shop)			

Generic Sketch (look up)	**A.** Food items (with FPM numbers)	**B**. Description of food item	**Tick for yes**	**C**. Item code	**D**. Amount usually eaten(g) Generic/amount = g	**E**. Eaten every day	**F**. Eaten every week	**G**. Eaten Occasionally	**H.** Never eaten	**Grams (g) /day**
						Times/ day	Times/ week			
	DAIRY-BLUE									
	1.Tea	Ordinary		4038						
		Herbal		4053						
		Rooibos		4054						
	1. Sugar in tea			3989						
	2. Milk in tea	Full cream		2718						
		Low fat 2%		2772						
		Skim fat free		2775						
		Other								
	1. Coffee			4037						
	2. Milk in coffee	Full cream		2718						
		Low fat 2%		2772						
		Skim fat free		2775						
	2. Sugar in coffee			3989						
	2. Milk as a drink	Full cream		2718						
		Low fat 2%		2772						
		Skim fat free		2775						
	3. Buttermilk/maas	Buttermilk		2713						
		Maas		2787						
	4. Milk drinks, flavoured									
X	**5. Yoghurt**	Fruit, LF, sweetened		2732						
		Plain LF		2734						

Generic Sketch (look up)	**A.** Food items (with FPM numbers)	**B**. Description of food item	**Tick for yes**	**C**. Item code	**D**. Amount usually eaten(g) Generic/amount = g	**E**. Eaten every day	**F**. Eaten every week	**G**. Eaten Occasionally	**H.** Never eaten	**Grams (g) /day**
						Times/ day	Times/ week			
	3. Breakfast cereals									
	2. Milk added to cereal									
	1. Sugar added to cereal			3989						
	9. Ice cream	Full cream		3519						
		Low fat		4325						
	9. Ice lollies			3982						
	ASK ABOUT TYPE OF BREAD,THICKNESS OF SLICES AND THE SPREAD									
	1. Bread/rolls	White		3210						
		Brown		3211						
		Whole wheat		3212						
		Traditional		3210						
	Toppings:	Roti			___ x 54g					
Meat										
Veg?										
	Spread? Y / N	**Brand name**			*Do you use spread every day on your bread?*					
	1. Brick margarine	HM		3484						
	1. Tub margarine	PUM		3496						
	1. other tub e.g. floro			3521						
	1. Butter			3479						
	Cheese spread	WM		2730						
	Fish paste			3109						
	Honey/syrup			3988						
	Jam			3985						
circle	**Marmite/Bovril**									

Generic Sketch (look up)	**A.** Food items (with FPM numbers)	**B**. Description of food item	**Tick for yes**	**C**. Item code	**D**. Amount usually eaten(g) Generic/amount = g	**E**. Eaten every day	**F**. Eaten every week	**G**. Eaten Occasionally	**H.** Never eaten	**Grams (g) /day**
						Times/ day	Times/ week			
	Sandwich spread			3522						
	Peanut butter			3485						
	Chocolate spread			9999						
	Cold meats	Ham		2967						
		Polony		2919						
		Salami		2948						
	6. Cottage cheese	Low fat		2729						
		Full fat		2759						
X	**7. Cheddar**			2722						
	7. Gouda			2723						
	7. Other cheese									
	8. Cheese wedges				2728					
	2. Fat cakes			3257						
	Any topping?									
(Red)	**QUARTER**	*Tick toppings:*								
	White bread			3210	¼ loaf = 225					
	Fried Chips			3740	1 portion = 90					
	Cheese			2722	___ slices x 20 =					
	Polony / French			2919	___ slices x 15=					
	Vienna (Russian)			2936	___ unit x 40 =					
	Fried egg			2869	___ medium x 45 =					
	Atchar			3117	___ Tsp x 40 =					
	Tomato sauce			3139	___Tsp x 25 =					
	Mashed potato			3876	¼ cup = 62.5					
	Mince meat, regular			2987						

Generic Sketch (look up)	**A.** Food items (with FPM numbers)	**B**. Description of food item	**Tick for yes**	**C**. Item code	**D**. Amount usually eaten(g) Generic/amount = g	**E**. Eaten every day	**F**. Eaten every week	**G**. Eaten Occasionally	**H.** Never eaten	**Grams (g) /day**
						Times/ day	Times/ week			
	4. Maize porridge stiff			3400						
	4. Maize porridge soft									
	2. Milk on soft porridge									
	1. Sugar on soft porridge			3989						
	1. Fat on soft porridge									
	4. Mabele/maltabella stiff			3241						
	4. Mabele soft									
	2. Milk on Mabele									
	1. Sugar on Mabele			3989						
	1. Fat on Mabele									
	4. Oats			3239						
	2. Milk on Oats									
	1. Sugar on Oats			3989						
	4. Maize & pumpkin porridge									
	5. Pasta/Pasta dishes									
	Remember to ask about added cheese! Grated?									
	6. Spaghetti Bolognaise	Regular mince		3260						
	6. Macaroni and cheese	WH, HM		3301						
	6. Lasagne	Regular		3261						

Generic Sketch (look up)	**A.** Food items (with FPM numbers)	**B**. Description of food item	**Tick for yes**	**C**. Item code	**D**. Amount usually eaten(g) Generic/amount = g	**E**. Eaten every day	**F**. Eaten every week	**G**. Eaten Occasionally	**H.** Never eaten	**Grams (g) /day**

						Times/ day	Times/ week			
	7. Rice	White		3247						
		Brown		3315						
circle *circle*	***Add anything?*** *Inkomazi /* *Plain yoghurt* *LF/WM*	*How much, t/T/S spoons?*								
tick	**Biryani: Chicken**									
	Mutton									
	Vegetable									
	7. Samp/mealie rice	With fat?								
	7. Samp and beans	With fat?		3402						
	7. Wheat rice			3249						
	8. Pizza (toppings?)									
	8. Savoury tart									
X	**EGGS-YELLOW**									
	Boiled/poached			2867						
	Fried	HM		2877						
		PUM		2878						
		Sun oil		2869						
tick	**Scrambled**	LFM, PUM		2888						
		LFM, Sun oil		2889						
		WM, HM		2890						
		WM, Sun oil		2873						
		WM		2872						
	Omelette (tick scrambled & add topping here)									

Generic Sketch (look up)	**A.** Food items (with FPM numbers)	**B**. Description of food item	**Tick for yes**	**C**. Item code	**D**. Amount usually eaten(g) Generic/amount = g	**E**. Eaten every day	**F**. Eaten every week	**G**. Eaten Occasionally	**H.** Never eaten	**Grams (g) /day**
						Times/ day	Times/ week			
	FRUITS-ORANGE									
X	**1. Apples**			4222						
X	**2. Bananas**	Fresh		3540						
	3. Berries	Fresh								
		Candied								
X	**4. Figs/prickly pears &**	Fresh								
	Coconuts, dates	Candied								
	5. Fruit salad	Fresh								
X	**6. Grapes**			3550						
X	**7. Guavas**	Fresh		3551						
		Canned juice		3628						
		Canned syrup		3553						
X	**8. Mango**	Fresh		3556						
		Canned syrup		3633						
	8. Pawpaw	Fresh								
	8. Kiwi fruit			3660						
	8. Lychees			3632						
	9. Watermelons			3576						
X	**9. Sweet melon**									

Generic Sketch (look up)	**A.** Food items (with FPM numbers)	**B**. Description of food item	**Tick for yes**	**C**. Item code	**D**. Amount usually eaten(g) Generic/amount = g	**E**. Eaten every day	**F**. Eaten every week	**G**. Eaten Occasionally	**H.** Never eaten	**Grams (g) /day**
						Times/ day	Times/ week			
X	**10. Naartjies**	Mineola fresh		4227						
		Naartjie fresh		3558						
		Naartjie canned in syrup		3635						
X	**11. Oranges**	Fresh		3560						
	11. Grapefruit	Fresh		3546						
X	**12. Peaches**	Fresh		3565						
		Canned syrup		3567						
X	**12. Nectarines**	Fresh		4228						
X	**13. Pears**	Fresh		3582						
		Canned syrup		3583						
	14. Pineapple	Fresh		3581						
X	**15. Plums**	Fresh		3570						
	15. Apricots			3534						
	16. Dried fruit									
	16. Dry stewed fruit									
	16. Raisins			3552						
	17. Fruit juice	Fresh								
		Sweetened								
		Unsweetened								

Generic Sketch (look up)	**A.** Food items (with FPM numbers)	**B**. Description of food item	**Tick for yes**	**C**. Item code	**D**. Amount usually eaten(g) Generic/amount = g	**E**. Eaten every day	**F**. Eaten every week	**G**. Eaten Occasionally	**H.** Never eaten	
						Times/ day	Times/ week			

	SOUPS, LEGUMES, NUTS									
	1. Soups	Powder, average		3158						
		Reconstituted (power + water)		3165						
		Vegetable		3162						
		Meat, lentil veg		3153						
		Dried bean, meat, veg		3145						
Type?	**2. Beans** (baked or other)									
Type?	**2. Lentils**									
Type?	**3. Nuts**									
	3. Peanuts									
	Peanuts & raisins									
	FISH & SEAFOOD- BEIGE *ask which type of fish was eaten?* ***Or if they don't know what colour was the meat of the fish?***									
	1. Fried fish	?								
	1. Fish cakes									
	1. Fish fingers									
Circ le	**1. Calamari**	Batter/ No batter								
Circle one	**2. Grilled/smoked/dried fish**	*?*								
	2. Haddock									
Circle one	**3. Pilchards & sardines**	Canned water		3055						
	Canned	Tomato sauce		3102						
		Mayonnaise		3488						
	3. Tuna	Brine water		3054						

Generic Sketch	**A.** Food items (with FPM numbers)	**B**. Description of food item	**Tick for yes**	**C**. Item code	**D**. Amount usually eaten(g) Generic/amount = g	**E**.	**F**.	**G**. Eaten Occasionally	**H.** Never eaten	**Grams (g) /day**

(look up)						Eaten every day	Eaten every week			
						Times/ day	Times/ week			
	3. Tuna	In oil		3056						
		Mayonnaise		3488						
	3. Pickled fish									
	MEAT- RED	*How do you eat meat? 1= with fat 2= fat trimmed*								
	1. Roast beef									
	1. Beef chops									
	1. Beef steak (bone)									
	1. Beef steak (no bone)									
	1. Beef stir-fry									
	1. Beef stew / veg			3020						
	1. Beef stew / cabbage			3006						
	2. Beef patties			2984						
	2. Mince	Regular		2987						
		With vegetables								
X	**2. Meatballs**	*Egg / no egg*								
	2. Cottage pie			3009						
	3. Burgers	Bun		3210						
	please tick, quantify, brand names (McDonalds bigmac)	Patty: Beef		2984						
		Cheese slice		2722						
		Tomato sauce		3139						
		Mayonnaise		3488						
Meal?	**Chips (fried)**	*Size?*		3740						
	Soft drink	*Size?*		3981						

Generic Sketch (look up)	**A.** Food items (with FPM numbers)	**B**. Description of food item	**Tick for yes**	**C**. Item code	**D**. Amount usually eaten(g) Generic/amount = g	**E**. Eaten every day	**F**. Eaten every week	**G**. Eaten Occasionally	**H.** Never eaten	**Grams (g) /day**
						Times/ day	Times/ week			
	3. Hot dog	Roll								
		Vienna								
		Tomato sauce		3139						
	3. Pita with…									
	3. Chicken burger	Bun		3210						
	please tick, quantify, name of burger (e.g KFC twister)	Crumbed, fried		3011						
		Cheese slice		2722						
		Tomato sauce		3139						
		Mayonnaise		3488						
Meal?	**Chips (fried)**	*Size?*		3740						
	Soft drink	*Size?*		3981						
	3. Chicken nuggets			3018						
	4. Chicken stew									
	4. Fried chicken pieces	With skin								
		Without skin								
	4. Roast chicken	With skin								
		Without skin								
	4. Chicken stir-fry									
	6. Fat cakes & mince									
	7. Meat pies *which meat?*									
Circle!	**7. Samoosas**	Beef / lamb								
		Chicken								
Circle!		Veg / cheese & corn / potato								

Generic Sketch (look up)	**A.** Food items (with FPM numbers)	**B**. Description of food item	**Tick for yes**	**C**. Item code	**D**. Amount usually eaten(g) Generic/amount = g	**E**. Eaten every day	**F**. Eaten every week	**G**. Eaten Occasionally	**H.** Never eaten	**Grams (g) /day**
						Times/ day	Times/ week			
	7. Sausage rolls			2939						
	7. Spring rolls			2918						
	8. Mutton stew no veg									
	8. Mutton stew with veg									
	8. Mutton leg chop									
	8. Mutton loin chop			2927						
	8. Roast mutton			2947						
	9. Spare ribs			3010						
	9. Pork chops			2930						
	9. Bacon			2906						
	9. Roast pork									
	10. Pork sausages			2932						
	10. Viennas			2936						
circle	**10. Frankfurters**	*Beef/pork/chicken*								
	10. Boerewors			2931						
	11. Traditional / organ meats									
	Chicken livers			2970						
	Chicken giblets			2998						
	Chicken head			2999						
	Chicken feet			2997						
	Liver & fat			2920						
	Sheep intestine / lungs			4342						
	Shank *pork/lamb/beef*									
Circle	**Mopani worms**	*Dried/ cooked*								

Generic Sketch (look up)	**A.** Food items (with FPM numbers)	**B**. Description of food item	**Tick for yes**	**C**. Item code	**D**. Amount usually eaten(g) Generic/amount = g	**E**. Eaten every day	**F**. Eaten every week	**G**. Eaten Occasionally	**H.** Never eaten	**Grams (g) /day**
						Times/ day	Times/ week			
	12. Vegetarian products									
	13. Dry sausages			2949						
	13. Biltong			2912						
	VEGETABLES – GREEN									
	1. Asparagus	Fresh boiled		3695						
		Canned boiled		4094						
	2. Avocado	Fresh		3656						
	3. Baby marrows	Fresh boiled		4171						
	Brinjal *(how cooked?)*									
	Okra *(how cooked?)*									
	4. Beetroot	Boiled		3698						
circle	*Grated / sliced*	Salad		3699						
	Chutney, onion,	Salad								
	5. Butternut	Boiled		3759						
		Boiled Sugar added		3989						
		Sugar & fat added		4273						
	5.Pumpkin	Boiled		4164						
		Sugar & fat added		3893						
	6. Broccoli, *Fresh/frozen*	Boiled								
		Fat added		3808						
	6. Cauliflower	Boiled		3716						
		Boiled + cheddar		3715						
	Quantify white/cheese sauce Pg 23									

Generic Sketch (look up)	**A.** Food items (with FPM numbers)	**B**. Description of food item	**Tick for yes for yes**	**C**. Item code	**D**. Amount usually eaten(g) Generic/amount = g	**E**. Eaten every day	**F**. Eaten every week	**G**. Eaten Occasionally	**H.** Never eaten	**Grams (g) /day**
						Times/ day	Times/ week			
	7. Cabbage	Boiled		3756						
	7. ..with potato, onion	HM		3813						
	7. ..with potato, onion	Sun oil		3815						
	7. coleslaw (mayo)			3705						
	7. Cabbage, *fried*	HM		3810						
	7. Cabbage, *fried*	Sun oil		3812						
	8. Carrots	Raw		3709						
	8. Carrots	Boiled		3757						
		Sugar added		3818						
	9. Gem squash	Boiled		3760						
		Boiled + sugar		3754						
	10. Green beans	Boiled		3696						
	10.. with potato, onion	No fat		3933						
	10.. with potato, onion	HM		3792						
	10.. with potato, onion	Sun oil		3794						
	11. Mealies	Whole, boiled		4133						
		Whole, boiled canned		4134						
	11. Sweet corn									
	12. Mixed vegetables	Canned, boiled		4264						
	carrot, corn, peas, green beans	Frozen, boiled		3727						
	caulif', carrot, green beans	Frozen, boiled		4265						
		Fresh boiled, PUM		3836						
		Fresh boiled, HM		3835						
	13. Mushrooms	Fried HM		3893						

Generic Sketch (look up)	**A.** Food items (with FPM numbers)	**B**. Description of food item	**Tick for yes**	**C**. Item code	**D**. Amount usually eaten(g) Generic/amount = g	**E**. Eaten every day	**F**. Eaten every week	**G**. Eaten Occasionally	**H.** Never eaten	**Grams (g) /day**
						Times/ day	Times/ week			
	13. Mushrooms	Fried in Sun oil		3841						
	14. Peas	Frozen boiled		4146						
		Boiled, sugar, HM		3859						
	15. Potatoes, Baked	(ate flesh & skin)		3736						
		(ate skin only)		3970						
		(ate skin, sour cream & chives		3973						
	Boiled	(ate skin & flesh)		4155						
		(ate no skin)		3737						
		HM		3867						
		PUM		3868						
	Croquette/cake			3915						
	Fried/sautéed	HM		3871						
		Sun oil		3873						
	Frozen, boiled			4156						
	Mashed	(SM, PUM)		3875						
		(WM, HM)		3876						
	Roasted in..	.. beef fat		3878						
		.. chicken fat		3923						
		.. lamb fat		3735						
		.. pork fat		3956						
		..Sun oil		3979						
	15. Potato Salad	(mayonnaise)		3928						
	Potatoes, whole canned			4159						

Generic Sketch (look up)	A. Food items (with FPM numbers)	B. Description of food item	Tick for yes	C. Item code	D. Amount usually eaten(g) Generic/amount = g	E. Eaten every day	F. Eaten every week	G. Eaten Occasionally	H. Never eaten	Grams (g) /day
						Times/ day	Times/ week			
	16. Potato chips	Fried in Sun oil		3740						
		Oven baked		3945						
		Mayonnaise		3488						
		Tomato sauce		3139						
	If take away where from?									
	17. Salad vegetables	French		3921						
		Greek		4271						
	Dressing? See pg 19!	Mixed green		3927						
	Raita (yoghurt, LF/ WM cucumber, tomato, onion)									
	17. Raw tomato			3750						
	17. Cucumber			3718						
	17. Peppers raw, green			3733						
	17. Onion, raw			3755						
	17. Onion, fried	HM		3844						
	17. Onion, fried	Sun oil								
	18. Spinach/morogo	boiled		3913						
		Boiled + HM								
		Boiled + PUM								
	18.. with potato, onion	HM		3901						
	18.. with potato, onion	Sun oil								
	19. Sweet potatoes	Baked, ate skin only		3748						
		Boiled, no skin		3903						
		Sugar + HM		3749						

Generic Sketch (look up)	**A.** Food items (with FPM numbers)	**B**. Description of food item	**Tick for yes**	**C**. Item code	**D**. Amount usually eaten(g) Generic/amount = g	**E**. Eaten every day	**F**. Eaten every week	**G**. Eaten Occasionally	**H.** Never eaten	**Grams (g) /day**
						Times/ day	Times/ week			
	20. Tomatoes, cooked	Fried, onion		3925						
		Fried, onion, peppers								
		Fried, onion, peppers, carrots								
	Fried onions (only)									
	FATS-TAN 'prompt'									
Circle	**1. Tub margarine**	Where used								
Circle	**1. Butter / Ghee**	Number of spoons								
	1. Brick Margarine	Number in family								
	2. White margarine (type of fat)									
	3. Cream and substitutes (brand, real dairy/plant fats)									
	4. Oils	Where used								
		Number of spoons								
		Number in family								
	5. Salad dressings	Homemade								
		Shop bought								
	5. Mayonnaise	Where used								
		Number of spoons								
		Number in family								

Generic Sketch (look up)	**A.** Food items (with FPM numbers)	**B**. Description of food item	**Tick for yes**	**C**. Item code	**D**. Amount usually eaten(g) Generic/amount = g	**E**. Eaten every day	**F**. Eaten every week	**G**. Eaten Occasionally	**H.** Never eaten	**Grams (g) /day**
						Times/ day	Times/ week			
	BISCUITS, CAKE & PUDDING - PURPLE									
	1. Biscuits/cookies	Commercial plain		3216						
brand		Commercial, filling		3217						
		Homemade, plain		3341						
	2. Biscuits/savoury	Provita		3235	___ x 6 g					
		Ry-vita		3236	___ x 5 g					
		Cream crackers		3230	___ x 8 g					
	High fat *(circle which one)*	Tuc/salticrax/kips		3331						
	Harvest wheat	Whole wheat		3391						
	Spread?									
	Topping?									
	3. Special buns *(hot cross, Danish, raisin)*			3409						
	3. Muffins	Bran		3407						
		plain		3408						
	3. Scones	plain		3237						
	4. Tart									
	4. Cake *(circle)*	Iced/Cream								
		Plain								
	5. Doughnuts	Plain		3232						
	5. Doughnuts	Jam		3423						
	5. Doughnuts	Icing		3422						
	5. éclairs			3268						
	5. Koeksisters			3231						

Generic Sketch (look up)	**A.** Food items (with FPM numbers)	**B**. Description of food item	**Tick for yes**	**C**. Item code	**D**. Amount usually eaten(g) Generic/amount = g	**E**. Eaten every day	**F**. Eaten every week	**G**. Eaten Occasionally	**H.** Never eaten	**Grams (g) /day**
						Times/ day	Times/ week			
X	**6. Pancakes/crumpets**	WM/Sun oil		3238						
	Toppings?									
	6. Waffles	WM/Sun oil		3238						
	Toppings?									
	7. Baked pudding									
	7. Trifle									
	7. Custard									
	7. Instant pudding									
	8. Rusks	Commercial		3329						
	9. Special breads	Banana loaf		3333						
		Date loaf		3256						
		Raisin bread		3214						
	Spread?									
	SNACKS, SWEETS & COLD DRINKS-PINK									
	1. Carbonated cold drinks e.g. coke			3981						
	1. Diet cold drinks e.g. diet coke			3990						
	2. Mageu			4056						
	2. Cold drinks (powder)									
	2. Energy drinks			4007						
	2. Squashes			3982						

Generic Sketch (look up)	**A.** Food items (with FPM numbers)	**B**. Description of food item	**Tick for yes**	**C**. Item code	**D**. Amount usually eaten(g) Generic/amount = g	**E**. Eaten every day	**F**. Eaten every week	**G**. Eaten Occasionally	**H.** Never eaten	**Grams (g) /day**
						Times/ day	Times/ week			
brands	**3. Crisps, potato** *(lays)*			3417						
Size & Circle!	**3. Crisps Savoury,** *(nik naks, fritos, ghost pops)*			3418						
	3. Popcorn, plain			3332						
	3. Popcorn, sugar coated			3359						
	4. Sweets									
	Lollipops									
Brands	**4. Chocolates**									
describe										
sizes										
	SAUCES & CONDIMENTS-GREY									
	1. Cheese sauce	LFM, HM, cheese		3126						
		LFM, PUM, cheese		3127						
		SM, PUM, cheese		3128						
		WM, HM, cheese		3125						

Generic Sketch (look up)	**A.** Food items (with FPM numbers)	**B**. Description of food item	**Tick for yes**	**C**. Item code	**D**. Amount usually eaten(g) Generic/amount = g	**E**. Eaten every day	**F**. Eaten every week	**G**. Eaten Occasionally	**H.** Never eaten	**Grams (g) /day**
						Times/ day	Times/ week			
	1. White sauce	LFM, HM		3143						
		LFM, PUM		3164						
		SM, PUM		3141						
		WM, HM		3142						
	2. Chakalaka									
	2. Atjar			3117						
	2. Tomato sauce & other									
	2. Chutney									
	ALCOHOLIC DRINKS-GREY									
	1. Beer (regular/low alcohol)									
	1. Cider									
	Coolers									
	2. Wine									
	2. Champagne									
	3. Spirits (any carbonated drink e.g. coke added)									
	4. Liqueurs & Fortified wine									
	OTHER: Karelas									

Appendix N: HREC Clearance Certificate (M171137)

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG	HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

03/06/2019

Professor SA Norris, et al
School of Clinical Medicine
Department of Paediatrics and Child Health
Developmental Pathways for Health Research Unit
Chris Hani Baragwanath Academic Hospital

Sent by e-mail to: san@global.co.za

Dear Professor Norris

Re: **Protocol Ref No: M171137**
Protocol Title: *Healthy life trajectories: Soweto young women's health survey*
Principal Investigator: Professor SA Norris, et al

Thank you for your e-mail of 15/05/2019.

I confirm that your proposed study amendments have been noted and approved. For the record, they are:

1. a change to the study inclusion and exclusion criteria, such that young women in the age range 18-25 may be included, irrespective of whether they have given birth
2. a subset of the participants (n=150) will take part in an expanded study to look at their nutritional knowledge and levels of physical activity

Thank you for keeping us informed.

Yours Sincerely

.....
Mr I Burns
For the Human Research Ethics Committee (Medical)

Works2000/lain0007/Acknowledge.docx

Appendix O: HREC Clearance Certificate (M190523)

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

R14/49 Mr Gudani Mukoma

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

CLEARANCE CERTIFICATE NO. M190523

NAME: (Principal Investigator)	Mr Gudani Mukoma
DEPARTMENT:	School of Clinical Medicine Paediatrics and Child Health SA MRC/Wits Developmental Pathways for Health Research Unit Soweto, Johannesburg
PROJECT TITLE:	Levers for intervention for diet and physical activity in older adolescents who have transitioned out of high school at varying socio-ecological levels
DATE CONSIDERED:	31/05/2019
DECISION:	Approved unconditionally
CONDITIONS:	
SUPERVISOR:	
APPROVED BY:	Dr C Penny, Chairperson, HREC (Medical)
DATE OF APPROVAL:	08/07/2019

This clearance certificate is valid for 5 years from date of approval. Extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Research Office Secretary in Room 301, Third floor, Faculty of Health Sciences, Phillip Tobias Building, 29 Princess of Wales Terrace, Parktown, 2193, University of the Witwatersrand. I/we fully understand the conditions under which I am/we are authorized to carry out the above-mentioned research and I/we undertake to ensure compliance with these conditions. Should any departure be contemplated, from the research protocol as approved, I/we undertake to resubmit the application to the Committee. **I agree to submit a yearly progress report**. The date for annual re-certification will be one year after the date of convened meeting where the study was initially reviewed. In this case, the study was initially reviewed May and will therefore be due in the month of May each year. Unreported changes to the application may invalidate the clearance given by the HREC (Medical).

Principal Investigator Signature

22/07/2019
Date

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

Appendix P: HREC Clearance Certificate (M170663)

UNIVERSITY OF THE WITWATERSRAND JOHANNESBURG

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

02/09/2020

Mr G Mukoma
School of Clinical Medicine
Department of Paediatrics and Child Health
Developmental Pathways for Health Research Unit
Chris Hani Baragwanath Academic Hospital

Sent by e-mail to: Gudani.Mukoma@wits.ac.za

Dear Mr Mukoma

Re: **Protocol Ref No: M170663**
Protocol Title: *Dietary practices in Black South African young adult men and women and adolescent boys and girls*
Principal Investigator: Mr G Mukoma

Thank you for your letter of 05/08/2020.

I confirm that your proposal to convene a series of virtual focus groups to discuss the knowledge and views of young Black persons regarding the COVID-19 pandemic has been noted and approved.

Thank you for keeping us informed.

Yours Sincerely

Mr I Burns
For the Human Research Ethics Committee (Medical)

Dr CB Penny, Chairperson, Human Research Ethics Committee (Medical)

Appendix Q: HREC Clearance Certificate (M160604)

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

18 April 2017

Prof Lisa Micklesfield

DPRHU
Parktown
Johannesburg
2193

Sent by email to: Lisa.Micklesfield@wits.ac.za

Dear Prof Micklesfield

Re: **Protocol Ref No: M160604**
Protocol Title: Determinants of Type 2 Diabetes Mellitus (T2D) Risk in Middle-Aged Black South African (SA) Men and Women: Dissecting the Role of Sex Hormones, Inflammation and Glucocorticoids
Principal Investigator: Prof Lisa Micklesfield
Protocol Amendment: Request to Collect Additional Data

This letter serves to confirm that the Chairman of the Human Research Ethics Committee (Medical) has approved the protocol amendment for the abovementioned protocol, as detailed in your letter dated 05 April 2017.

The following documents were received:

- Cover Letter dated 05 April 2017.
- Participant Information Sheet version 1.0 dated April 2017.
- Informed Consent version 1.0 dated April 2017.
- FBQ Questionnaire dated 2017.

Thank you for keeping us informed and updated.

Yours Sincerely,

L. Moeng

Mr Lebohang Moeng
Administrative Assistant
Human Research Ethics Committee (Medical)

UNIVERSITY OF THE WITWATERSRAND
OFFICE OF THE DEPUTY VICE CHANCELLOR RESEARCH
18 APR 2017
RESEARCH OFFICE HREC (Medical)
JOHANNESBURG

Appendix R: Article 1 – Chapter 3

South African Journal of Clinical Nutrition 2022: 1–8
https://doi.org/10.1080/16070658.2022.2076374

SAJCN
ISSN 1607-0658 EISSN 2221-1268

ARTICLE

The relationships between socioeconomic status, dietary knowledge and patterns, and physical activity with adiposity in urban South African women

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Background: This cross-sectional study examined the relationship between socioeconomic status (SES), dietary knowledge and patterns, and physical activity level with body mass index of urban South African young women.
Methods: Data were collected on 160 black South African women (aged 18–24 years) and included household SES, food frequency and nutritional knowledge questionnaires, self-reported physical activity and anthropometry. To assess household SES index, 1–7 assets were categorised as a lower household SES and those with 8–13 assets as a higher household SES. Structural equation modelling analysis was used to determine the direct, indirect and total effects on adiposity of household SES, age, education, nutrition knowledge score, dietary patterns and physical activity.
Results: The prevalence of overweight and obesity was similar among women from high SES households compared with their low SES peers (48.4 vs. 44.8%). More than half (53%) of the women had poor dietary knowledge. Women from low SES households spent more time in moderate to vigorous intensity exercise (MVPA) compared with their high SES counterparts. Two distinct dietary patterns (Western and mixed) were identified. SEM results show that a unit increase in adherence to the 'Mixed' dietary pattern compared with 'Western' was associated with a 0.81 lower BMI kg/m^2 (95% CI −1.54; −0.08), while ≥ 150 minutes' MVPA per week was associated with a 1.94 lower BMI kg/m^2 (95% CI −3.48; −0.41).
Conclusion: The associations of SES, diet and physical activity on BMI must be taken into account when developing and designing interventions that target improvement in young women's health.

Keywords: body mass index, dietary patterns, obesity, physical activity, socioeconomic status

Introduction

The obesity epidemic continues to rise rapidly in low- and middle-income countries, particularly in Africa, despite the high prevalence of food insecurity and undernutrition.[1,2] Currently, South Africa has the highest obesity prevalence in sub-Saharan Africa (SSA),[3] with the latest national survey reporting a 68% prevalence of overweight and obesity in adult women, and 40% in young women between 15 and 24 years.[4] Using data from the Birth to Twenty Plus cohort in Soweto, Nyati *et al.*[5] also report this rise in combined prevalence from 11 years of age, reaching 46.5% in the 21+ years of age in urban young women. Alongside this, poor nutritional knowledge has also been reported in young South African women.[6]

The role of a healthy diet and regular physical activity (PA) in the prevention of obesity and associated non-communicable diseases (NCDs) is well documented.[7] Research has shown that lifestyle behaviours, including diet, PA, smoking and alcohol intake, during adolescence are often maintained into adulthood, influencing the risk of obesity and NCDs.[8] Research data also show that healthier diets are associated with higher socioeconomic status (SES) levels, while there are data to support poorer diets because of choice-constrained conditions, along a continuum representing factors over which the individual has little or no control, to those for which they have greater agency.[9,10] Since 1994, the consumption of meat, fats and oils, sauces, dressings and condiments, sweet and savoury snacks and soft drinks has increased in South Africa by more than 30%.[11] High consumption of these foods has been associated with weight gain, higher obesity prevalence and other NCDs in adults and children.[11]

Research has well described upstream factors such as household SES, mass media exposure and urbanisation as important determinants of shifting dietary habits and physical inactivity that are associated with an increased risk of NCDs and premature mortality.[12,13] This is exacerbated in African countries that are rapidly urbanising with increased access to energy-dense, low-quality foods, alongside persisting food insecurity.[14] Understanding the complexity of the interaction between household SES and health behaviours is necessary to inform public health intervention development to curb the rising obesity prevalence in African women in poor urban settings. The aim of this study was to examine the relationship between household SES, dietary knowledge and patterns, and physical activity (PA) level, with adiposity (body mass index [BMI]) of urban South African young women.

Materials and methods

Study sample and design

This cross-sectional study was conducted at the South African Medical Research Council (SAMRC)/Wits Developmental

Pathways for Health Research Unit (DPHRU) at the Chris Hani Baragwanath Academic Hospital (CHBAH) in Soweto. CHBAH is one of the largest hospitals worldwide and a public tertiary care institution that serves the low-income community of greater Soweto in south-western Johannesburg, South Africa. Soweto is one of the most well-known historically disadvantaged townships in South Africa known for its established communities, and its socioeconomic and cultural variations.[15]

In 2019, as part of a larger package of work by the Global Diet and Activity Research (GDAR) Network, explained in more detail elsewhere,[16] we recruited a convenient sample of 160 black young women participants between the ages of 18–24 years from the Soweto household enumeration study,[17] which included individuals and household data from over 2 000 households in Soweto. Through this database, research assistants contacted prospective participants using their provided contact details, inviting them to participate. All participants from the Soweto household enumeration study had given consent to be contacted for any future studies. The database also enabled the identification and recruitment of participants from low- and high-income households to ensure socioeconomic diversity.[16] All participants gave written informed consent prior to taking part in the study. The Human Research Ethics Committee (HREC) of the Witwatersrand University, under ethics numbers M171137 and M190523, granted ethical approval.

Anthropometry

All measurements were performed with participants in light clothing and without shoes. The participant's height (in mm) was measured using a Seca 213 portable stadiometer (Seca Deutschland, Hamburg, Germany) and converted to metres (m). Bodyweight was measured to the nearest 0.1 kg using a portable electronic scale. Body mass index (BMI) was calculated as weight in kilograms (kg) divided by height $(m)^2$.

Socioeconomic status

Questionnaires were completed via interview by trained research assistants. To assess the household socioeconomic status (SES), an asset index was determined and comprised the sum of assets out of a possible 13 (electricity, refrigerator, stove, vacuum cleaner, washing machine, digital satellite TV, DVD, car, landline, mobile phone, personal computer, Internet).

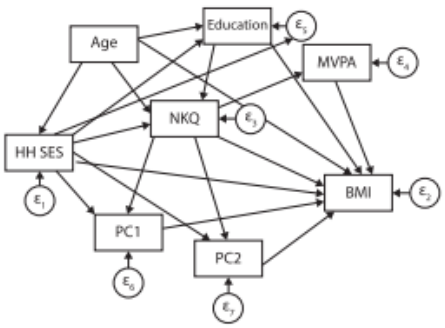

Figure 1: Conceptual framework for the association between household SES, age, education, nutritional knowledge (NKQ), Western dietary pattern (PC1), Mixed dietary pattern (PC2) and MVPA with BMI among young women.

Young women with 1–7 assets were categorised as having a lower household SES index and those with 8–13 assets as having a higher household index category. This index has been described as a useful method for determining socioeconomic status in this setting.[18] All young women were required to report the highest level of education that they had successfully completed, and this was then categorised into some secondary education, completed secondary education and tertiary education.

Dietary assessment

A standardised quantitative food frequency questionnaire (QFFQ), designed for the South African population, was used to collect dietary intake data. The SAMRC developed this tool using results from dietary surveys in both urban and rural areas since 1983.[19] The QFFQ comprises 214 food items that represent foods consumed by at least 3% of the population. This tool has been piloted and utilised extensively in Soweto, as described elsewhere.[20,21] In order to complete the QFFQ, trained research assistants used high-quality photographs of food items to trigger participants' memories of all foods and beverages consumed during the previous seven days.[20,22] The participants were asked to arrange the cards into three piles: foods eaten in the last seven days, foods eaten occasionally, or foods never eaten, and this was recorded. The QFFQ was then administered and took approximately 40–50 minutes to complete. With food items that were consumed in the past seven days, additional data on the frequency and quantity of consumption was recorded. Portion sizes were estimated using a combination of high-quality two-dimensional drawings of foods, household utensils and three-dimensional food models, which have been described and validated by Steyn *et al.*[22] Estimated portion sizes were converted to grams to allow for calculation of the participant's average intake of the food items consumed over the previous 7 days. The QFFQ was captured and managed online using REDCap electronic data capture tools hosted at the University of the Witwatersrand.[23] Using the South African Food Composition Tables,[24] nutrient composition (energy and macronutrients) was calculated from conversion of single food item intakes by the SAMRC.

The nutrition knowledge questionnaire was adapted from previously validated instruments,[25] but has not been used in this context previously. Nutritional knowledge was determined using a summative score comprising 4 knowledge components: knowledge of advice from experts, classification of food groups, choosing foods, and diet-related health problems, and was adequate or good when it was ≥ 32 out of the maximum score of 63. Inter-item analysis was used to assess internal consistency (Cronbach's alpha = 0.80).

Physical activity and sedentary behaviour

The Global Physical Activity Questionnaire (GPAQ), developed for global physical activity surveillance, was completed via interview to ascertain self-reported physical activity.[20] Total moderate-to-vigorous intensity physical activity (MVPA) in minutes per week (minutes/week) was calculated by adding occupation, travel-related and leisure-time moderate and vigorous intensity physical activity. MVPA was sufficient if a participant met the World Health Organization's (WHO) recommendation of ≥ 150 minutes per week.[26]

Data analysis

Data were analysed for 160 young women with complete data using STATA SE 15.1 (StataCorp, College Station, TX, USA).

Descriptive characteristics of the sample are presented as median (interquartile range) and percentages (%) for continuous and categorical variables, respectively. Study characteristics were compared between participants with low household SES index and high household SES index using the Kruskal–Wallis rank test for continuous data and chi-square tests for categorical data. Principal component analysis (PCA) was used to identify dietary patterns. This method groups variables, food items or groups based on the level of correlation with each other to form new linear components that reflect combinations (patterns) of intake in a population. PCA was conducted on the weekly consumption of the food items listed in the QFFQ, which were classified into 49 food groups according to their nutrient composition and usage. These groupings were based on those used and described extensively by Crozier *et al.*[27] PCA was applied using orthogonal (varimax) rotation and the Kaiser–Meyer–Olkin measure of sampling adequacy (0.65), and Bartlett's test of sphericity ($p < 0.001$) confirmed PCA to be an appropriate dimension reduction technique to apply in this sample. Eigenvalues, as well as their visual inflections on a scree plot, and the total variance explained (percentages) were used to identify retained patterns (Figure 1). As described elsewhere, foods or food groups that had factor loading scores ≥ 0.3 on the PCA matrix reflected strong associations with principal components and these were used to name dietary patterns.[28]

Multivariate linear regression models were computed to assess the association between household SES index, age, education, nutrition knowledge score, Western and mixed dietary patterns, and MVPA as predictors, and BMI as the outcome variable, for the whole group and then stratified by SES group. Collinearity between the variables was checked by calculating the variance inflation factor (VIF), with the highest VIF being recorded at 1.19. A VIF > 10 is considered significant collinearity.

Structural equation modelling (SEM) analysis was used to determine the direct, indirect and total effects of household SES, age, education, nutrition knowledge score, Western and mixed dietary patterns and MVPA on BMI. To evaluate the best fitting model for our data, we reported goodness-of-fit indices including chi-square test, root mean squared error of approximation (RMSEA), Tucker–Lewis index (TLI), coefficient of determination (CD) and standardised root mean squared residual (SRMR). Statistical significance was considered when the *p*-value was less than or equal to 0.05.

Results

Descriptive statistics of young women living in Soweto

The study included 160 urban black young women with a median age of 21 years. Overall, 46.6% of participants were overweight or obese, with the prevalence being similar among women from high SES households (48.4%) compared with their low SES counterparts (44.8%). More than half (53%) of the women had poor dietary knowledge. In contrast, young women from households with a low SES (range = 163; 840 min/week) spent significantly more time engaging in MVPA compared with their high SES counterparts (range = 105; 540 min/week) (Table 1).

Top 10 most frequently consumed foods by young women

The top 10 most frequently consumed food items data show little variation in consumption frequency between young women from households with high and low SES index in most of the food items consumed but modest differences in intake of fruits and vegetables. Cooking oils, vegetables and sugar were the top three most frequently consumed foods in both

Table 1: Descriptive characteristics of young women living in Soweto

Participants' characteristics	Total, *n* = 160	Low household SES index, *n* = 67	High household SES index, *n* = 93	*p*-value[a]
Age (years)	21 (20; 23)	21 (20; 23)	21 (19; 22)	0.31
Height (m)	1.59 (1.55; 1.64)	1.59 (1.56; 1.64)	1.59 (1.54; 1.62)	0.23
Weight (kg)	62.2 (50.8; 75.2)	61.7 (50.1; 75.9)	63.1 (52.2; 73.3)	0.78
BMI (kg/m^2)	24.1 (21; 28.8)	23.7 (20.6; 28.8)	24.70 (21; 29.50)	0.46
BMI classification, *n* (%):				
Underweight (< 18.4 kg/m^2)	18 (11.2)	8 (11.9)	9 (9.7)	0.95
Normal (18.5–24.9 kg/m^2)	67 (42.2)	29 (43.3)	39 (41.9)	
Overweight (25–29.9 kg/m^2)	40 (24.8)	16 (23.9)	24 (25.8)	
Obese (> 30 kg/m^2)	35 (21.7)	14 (20.9)	21 (22.6)	
Household SES index (sum of assets)	8 (7; 10)	6 (5; 7)	9 (8; 10)	≤ 0.001
Highest level of education, *n* (%):				
Some secondary education	33 (21)	15 (22.4)	19 (20.4)	0.69
Completed matric	92 (57.4)	36 (53.7)	56 (60.2)	
Tertiary	35 (21.6)	16 (23.9)	18 (19.4)	
Nutritional knowledge score	32 (28; 35)	31 (26; 35)	32 (28; 35)	0.10
Nutritional knowledge, *n* (%):				
Good	75 (46.9)	35 (52.2)	40 (43)	0.24
Poor	85 (53.1)	32 (47.8)	53 (57)	
Total MVPA (minutes/week)	310 (105; 660)	390 (163; 840)	240 (105; 540)	0.05
PA levels, *n* (%):				
Not meeting recommendations	68 (42.5)	30 (44.8)	55 (59.1)	0.62
Meeting recommendations	92 (57.5)	37 (55.2)	38 (40.9)	

Data are summarised as median (IQR) or *n* (%); recommended MVPA is ≥ 150 min/week, MVPA – moderate vigorous physical activity; Good nutritional knowledge is ≥ 32;
[a]Kruskal–Wallis test (continuous variables), chi square test (categorical variables).

low and high SES household groups. However, the data show large differences in consumption of white bread and carbonated soft drinks, which was at least four times per week in young women from households with low SES index compared to zero in young women from households with high SES index, and consumption of red meat and soup powder, condiments and sauces was at least five times per week in young women from households with high SES index compared with zero in young women from households with low SES index (Figure 2).

Identification and description of depicted dietary patterns

Two distinct dietary patterns were extracted from the PCA, which together explained 32.9% of the variation in food intake. The first principal component (PC) was characterised by high factor loadings for sugar (0.829), tea and coffee (0.722), cooking fats (0.517), full-fat milk (0.444), breakfast cereals (0.431), red meat (0.407), vegetables (0.371), soup powder, condiments and sauces (0.365), processed meat (0.351), brown wholemeal bread (0.336) and fruit juice (0.336), and was labelled the 'Western' dietary pattern (19.8% variance). The second PC had high factor loadings for processed meat (0.559), red meats (0.558), fruits (0.516), vegetables (0.402), yoghurt, buttermilk and maas (0.336), cakes and biscuits (0.335), rice and pasta (0.326), soup powder, condiments and sauces (0.304), and fruit juice (0.301) (13.2% variance). This PC was labelled the 'Mixed' dietary pattern (Supplementary Table).

Multivariate linear regression analysis showing correlates with BMI

Overall, age was positively associated ($p \leq 0.001$), and the 'Mixed' dietary pattern was negatively associated ($p < 0.05$) with BMI. Among young women from households with a low SES index, the 'Mixed' dietary pattern ($p < 0.05$), and MVPA ($p < 0.05$) were inversely associated with BMI. For those with a high household SES index, only age ($p < 0.05$) was associated with BMI (Table 2).

Structural equation modelling for the direct and indirect effects of household SES, age, education, dietary (knowledge and patterns) and MVPA on BMI

The structural equation model (SEM) for the direct and indirect effects of household SES, age, education, dietary knowledge, the Western and Mixed dietary patterns and MVPA on BMI is presented for the overall sample in Table 3 and Figure 1. The model showed a good comparative fit index (CFI) of 0.96 and

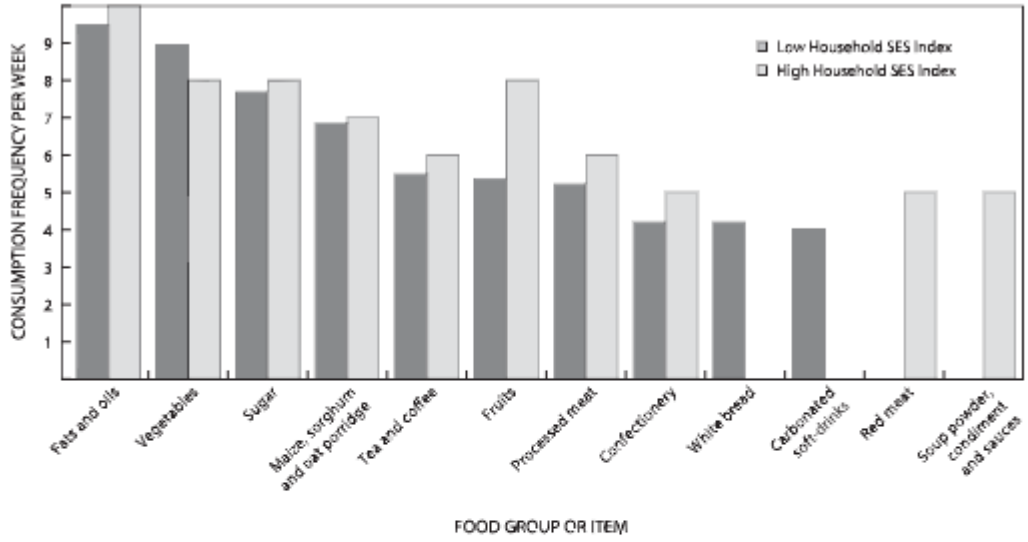

Figure 2: Top 10 foods most frequently consumed by young women.

Table 2: Multivariate linear regression coefficients for BMI among young women

Factor	Total B (95% CI)	Low household SES B (95% CI)	High household SES B (95% CI)
Age (years)	0.62 (0.10; 1.15)*	0.41 (0.25; 1.06)	0.56 (0.01; 1.12)*
Education level	0.83 (1.82; 0.12)	0.55 (2.06; 1.05)	1.20 (2.72; 0.32)
Household SES index	0.06 (0.31; 0.43)	0.03 (0.88; 0.94)	0.22 (1.07; 0.63)
Nutritional knowledge score	0.01 (0.16; 0.18)	0.13 (0.34; 0.09)	0.10 (0.10; 0.31)
Western dietary pattern	0.23 (0.53; 1.01)	0.41 (1.85; 1.04)	0.35 (0.61; 1.29)
Mixed dietary pattern	0.77 (1.54; 0.01)*	1.52 (2.78; 0.28)*	0.29 (1.28; 0.70)
MVPA (min/week)	1.31 (2.74; 0.11)*	0.67 (3.35; 1.93)*	1.23 (2.96; 0.49)

B = beta coefficient; CI = confidence interval; SES = socioeconomic status; MVPA = moderate to vigorous physical activity; total $R^2 = 0.196$; low household SES index $R^2 = 0.139$; high household SES index $R^2 = 0.143$; * $p \leq 0.05$.

Table 3: SEM for the association between household SES, age, education, nutritional knowledge, diet and physical activity and BMI

Effect of	Direct effect (95% CI)	Indirect effect (95% CI)	Total effect (95% CI)
Household SES	0.07 (0.34; 0.48)	0.06 (0.06; 0.18)	0.13 (0.24; 0.48)
Age	0.61 (0.19; 1.03)**	0.32 (0.01; 0.62)	0.63 (0.01; 0.91)**
Education	0.83 (0.89; 0.24)	0.70 (0.12; 1.52)	0.10 (0.27; 0.48)
Nutritional knowledge score	0.001 (0.16; 0.18)	0.01 (0.03; 0.06)	0.02 (0.14; 0.18)
Western dietary pattern	0.49 (0.29; 1.28)	0.04 (0.17; 0.08)	0.21 (0.69; 1.13)
Mixed dietary pattern	0.81 (1.54; 0.08)*	0.11 (0.07; 0.28)	0.77 (1.52; 0.02)*
MVPA (min/week)	1.94 (3.48; 0.41)*	0.11 (0.13; 0.35)	1.65 (3.12; 0.12)*

All values are coefficients (95% confidence interval); significance levels: * $p \leq 0.05$; ** $p \leq 0.01$; fit indices: LR test of model vs. saturated: chi square (2) = 0.240, prob > chi square = 0.000; RMSEA = 0.04; CFI = 0.96 comparative fit index; TLI = 0.86 Tucker–Lewis index; SRMR = 0.05: Standardised root mean squared residual, CD = 0.15 coefficient of determination.

a good standardised root mean squared residual (SRMR) of 0.05. The SEM showed that age (95% CI 0.19; 1.03, $p < 0.01$) had a direct effect on BMI. The 'Mixed' dietary pattern and MVPA had direct inverse and significant effects on BMI. A unit increase in the 'Mixed' dietary pattern was associated with 0.81 lower BMI kg/m^2 (95% CI = −1.54; −0.08), while ≥ 150 min MVPA per week was associated with almost a 2 lower BMI kg/m^2 (95% CI = −3.48; −0.41, $p < 0.05$).

Discussion

We assessed the relationship between household SES, dietary knowledge and patterns, and physical activity level and the adiposity of urban South African young women. The results have shown that age, the 'Mixed' dietary pattern, and MVPA have a significant relationship with BMI. However, these relationships exist only in young women from low SES households compared with those from high SES households. Age was positively and significantly associated with BMI overall. The 'Mixed' dietary pattern, with a high intake of meat, fruits, vegetables, processed and energy-dense foods, and MVPA were inversely and significantly associated with BMI in young women from households with low SES index. Using structural equation modelling, the results highlight that the direct and total effect of age (positive), the 'Mixed' dietary pattern and MVPA (inverse) on BMI is significant.

The association between age and BMI and the high prevalence of overweight and obesity in this study is in line with previous findings that show the prevalence of overweight/obesity to be increasing with age.[29,30] The overall reported prevalence of overweight/obesity in this study (46.6%) is similar to findings reported by Micklesfield *et al.*[30] and Munthali *et al.*,[31] in a cohort of young women from Soweto and Agincourt of a similar age (18–21 years), which found a 46.5% prevalence of overweight/obesity.

While other studies in urban South African women by Gradidge *et al.*[32] and Munthali *et al.*,[31] with the same cohort of women as the Micklesfield study, found associations between SES and BMI, this study's findings did not provide any substantial evidence of a direct or indirect effect. Instead, this study provided evidence concerning the rising prevalence of overweight and obesity in South African young women in low and high SES groups. Additionally, this study's findings and those of Micklesfield *et al.*[30] may provide an alert that current health promotion policies such as the 2018 sugar-sweetened beverages (SSB) tax have minimal impact on influence healthy eating behaviour in young South African women.[21,33] Similar to findings in the 2013 South African National Health And Nutrition Examination Survey (SANHANES-1),[34] more than half of the young women in this study had poor or low nutrition knowledge, which is regarded as one of the reasons for poor food choices and the development of malnutrition that leads to obesity and NCDs.[35]

The observed inverse associations of the 'Mixed' dietary pattern and physical activity with BMI in this study could represent important targets for interventions. Comparable studies evaluating the relationship of dietary patterns and BMI in young adult women are scarce. However, evidence exists from several studies done in South Africa that have reported differently on associations between dietary patterns and BMI increase in adolescents and adult women, whereby the patterns were described as 'Western pattern'[20] or similar 'animal derived pattern'.[36,37] These dietary patterns had high intakes of red meat, processed meat, high-sugar drinks, candy and sweets, fried foods, butter and other high-fat dairy products.[20,36,37] The findings of Wrottesley *et al.*[20] are also different from the current study as they show that a 'mixed dietary pattern' made up of high intakes of fats and sugars was associated with weight gain during pregnancy in a Soweto study. Whilst the 'Mixed' dietary pattern found in this study is heterogeneous, it could be that the high intake of fruits, vegetables and dairy products is a potential driver of the inverse association with BMI. However, as this dietary pattern also has high loadings of processed meat, cakes and biscuits, and red meat, it may be showing a transition towards a high-energy dense and micronutrient-poor diet, which is associated with elevated adiposity.[38] In addition, 7/10 and 6/10 (high SES vs. low SES) of the food items consumed by young women in this study are linked to a micronutrient-poor diet.[20] Previous research has linked the increasing rate of obesity with a nutrition transition characterised by consumption of Western diets high in refined carbohydrates, added sugar and fat, as well as reduced physical activity, particularly in the African context.[37,39–41] More studies have reported associations between fats and sugars with greater adiposity.[42–46] In this study, fats and sugars were among the top three foods most frequently consumed by young women.

The relationship between physical activity and SES is complex.[47,48] Similar to other studies nationally and internationally,[12,49] our study shows that MVPA was higher (6.5 hours per week) in the low household SES group compared with the high household SES group (4 hours per week). While other previous studies found that lower SES status was associated with more sedentary activities such as watching television,[50] our results found low household SES index to be associated with more time spent on MVPA and an association between MVPA and BMI. The difference in these findings may be because of young women from households with lower SES index needing to assist more with household chores or walking more than

their high SES peers. This further supports findings which showed that individuals who maintain PA at recommended levels have smaller increases in BMI.[30,51] However, that almost 60% of young women in the high household SES group do not meet the ≥150 minutes per week as recommended by the WHO is of great concern as it shows poor levels of physical activity in this age group. The direct, inverse and significant effect on BMI of moderate-to-vigorous physical activity supports the findings that PA can be incorporated when designing interventions to reduce the risk of overweight and high body fat percentage in a population.[52]

This study has some limitations. Our study was cross-sectional, and we cannot make robust conclusions concerning causality in the observed associations. Reported dietary data have limitations in misreporting, and they can differ by demographic variables such as age and level of education. Our study focused only on young women. We need similar analyses in young men to identify how sex may influence the relationships and help to target interventions to men and women in South Africa. The methods included clinical measures of BMI and although self-reported measures of physical activity and sedentary behaviour were used, these methods have been validated in similar populations. The strengths also include the use of a validated QFFQ, and the PCA technique used for the present analysis to derive the dietary patterns is known to depict real-world dietary behaviours. Given that individuals do not consume nutrients or foods in isolation, the elucidation of dietary patterns that describe the overall diet, alongside the assessment of structural effects of the different individual, socioeconomic and lifestyle behaviour factors on adiposity are a particular strength of this study.

While the South African government interventions were targeted to reduce the percentage of people who are obese or overweight by 10% in 2020, with current economic and nutrition transitions it is critical that public health interventions foster greater intake of micronutrient-rich foods and maintenance of regular exercise. In a country that is already burdened by inequality, overpopulation in urban areas, high unemployment rates, unhealthy lifestyle behaviours and poor health systems, effective multi-sectoral interventions are warranted. Findings in this study can be useful in updating the current scientific knowledge: for example, an update to the latest obesity prevention and control strategy will show whether the set target was achieved, if the structural interventions to make healthier food and exercise choices were effective, and if household economic protection efforts such as access to farming land and better paid employment opportunities can improve the existing interventions. Thist will further enable the identification of gaps that still need to be addressed for the target to be achieved.

Conclusion

Our study suggests that it is important to consider the obesity risk of young women in the development of health-promotion strategies in South Africa. We recommend that future dietary, physical activity, educational and promotional programmes provide targeted strategies and guidelines suitable for young women with different SES backgrounds. In addition, our findings also suggest that healthy dietary practice, while necessary, is insufficient to facilitate pragmatic behaviour change. In combination with physical activity and dietary knowledge (despite not being associated with BMI), practical strategies are needed to motivate and facilitate behaviour changes that protect health in the short, medium and long term.

Declarations

Ethics approval and consent to participate – The Human Research Ethics Committee (HREC) of the Witwatersrand University, under ethics numbers M171137 and M190523, granted ethical approval.

Consent for publication – All participants gave written informed consent prior to taking part in the study.

Availability of data and materials – The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Disclosure statement – No potential conflict of interest was reported by the authors.

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Appendix P: Article 4 – Chapter 6

nutrients

MDPI

Article

Nutrient Patterns and Body Mass Index: A Comparative Longitudinal Analysis in Urban Black South African Adolescents and Adults

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Abstract: Objective: We set out to evaluate the association between nutrient patterns and general adiposity in black South African adolescents and adults and to determine whether the interactions are longitudinally sustained over 24 months. Methods: Principal Component Analysis (PCA) was used to derive the nutrient patterns of 750 participants (250 adolescents between 13 and 17 years old and 500 adults who were 27 years or 45^{+} years old). PCA was applied to 25 nutrients, computed from the quantified food frequency questionnaire (QFFQ) over a 24 months period. Results: The nutrient patterns between adolescents and adults were similar over time; however, their associations with BMI were different. Among the adolescents, only the "plant-driven nutrients pattern" was significantly associated with a 0.56% (95% CI (0.33; 0.78); $p < 0.001$) increase in BMI. Among the adults, the "plant-driven nutrient pattern" (0.43% (95% CI (0.03; 0.85); $p < 0.001$) and the "fat-driven nutrients pattern" (0.18% (95% CI (0.06; 0.29); $p < 0.001$) were significantly associated with a BMI increase. Furthermore, the "plant-driven nutrient pattern", "fat-driven nutrient pattern" and the animal-driven nutrient pattern revealed sex differences in their association with BMI. Conclusion: Urban adolescents and adults had consistent nutrient patterns, but their BMI relationships changed with age and gender, an important finding for future nutrition interventions.

Keywords: BMI; obesity; nutrient patterns; plant protein and fats; PCA

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1. Introduction

Obesity is a global epidemic [1,2]. Obese people have a greater likelihood of dying from NCDs such as diabetes and heart disease [3–5]. In 2016, 13% of adults (18 years and older) worldwide were obese (11% men, 15% women) [6]. Recent studies suggest that over 70% of the world's obese population live in developing countries [7]. South Africa now leads Sub-Saharan Africa in obesity prevalence [2,4]. Women (68%) are more likely to be overweight or obese than men (31%) [8]. South African adolescents are also becoming overweight or obese (9% of boys and 27% of girls), similar to several high-income countries [8,9]. This combined prevalence has increased from age 11 to 46.5% in the 21+ age group in South African urban settings, indicating that adolescent NCD risk is rising rapidly [10]. Thus, more research is needed to understand the alarming rise in obesity rates and why more women than men are affected [11].

Obesity is linked to a sedentary lifestyle, poor diet, low physical activity and insufficient sleep [12]. South Africans of all ages exercise less due to economic changes and urbanisation [13–15]. Adults with higher SES have lower PA and a higher BMI [16,17]. The ongoing nutritional transition has led to more people eating westernised foods (meat, fats and oils, sauces, dressings, condiments, sweets and soft drinks) [5]. This diet increases the weight and BMI of children and adults [4,8]. In women, obesity reduces female fertility and

increases offspring obesity [18]; a high maternal BMI may increase the birth and childhood weight due to the elevated maternal glucose and insulin concentrations, which drive foetal growth and adiposity [19]. Although a mother's diet affects her offspring's long-term health, little is known about a father's diet [20]. However, father's lifestyle, sperm quality and offspring health are linked [21]. Male sperm counts decrease when men eat a western-style diet, which is high in sugar, fat and processed foods [22]. Furthermore, high-fat diet-induced paternal obesity damages the sperm DNA, reduces blastocyst development and implantation rates and causes subfertility in male and female offspring for up to two generations [23]. Thus, the preconception risk factors for both men and women—healthy body composition, physical activity and diet—must be addressed [24].

Research shows that poor eating habits start in the early stages of life [12]. However, nutrient patterns in adolescents are rarely studied [13]. In addition, many of the studies conducted [25–27] have only examined how single nutrients and foods affect obesity. Nutrient patterns across all age groups are important because humans eat different foods [28–31]. Several South African studies have examined nutrient patterns and adiposity in different age groups and settings [28,30–32]. Only one rural South African adolescent study found that animal-driven nutrient patterns increase BMI [28]. Urban adolescents have no data on this association. In other studies of urban middle-aged South African adults, animal-driven nutrients [32], also called animal and fat-driven nutrients [30], were associated with an increased BMI. The association was stronger among men than women [30]. It is unknown whether there are also sex differences between boys and girls among urban adolescents. Only one study of middle-aged women showed that dietary patterns remained the same over time [31]. However, data exploring this in men is not available. In addition, in a publication [33] that forms part of this papers series, we found that young women of low socioeconomic status (SES) who ate a mixed diet (meat, vegetables, fruit, dairy, starch, cakes and biscuits) and did moderate-vigorous physical activity (MVPA) had a lower BMI than women of high SES. Despite being overweight or obese, young women with low household SES had a lower risk of NCDs than those with high SES [14]. Even with these results, it was unclear whether eating patterns change over time, if they are the same for teens and adults and if they relate to BMI differently for men and women. As most of the previous studies were cross-sectional, conducted in different age groups and settings [28,30,32] and only adult women were studied longitudinally [31], this paper aims is to build on our previous findings and other research [28,34,35] in South Africa by using nutrient pattern analysis to compare the unique eating patterns of adolescents and adults and assess their longitudinal (24 month period) effects on BMI.

2. Materials and Methods

2.1. Study Population and Design

Our study was conducted at the South African Medical Research Council (SAMRC)/Wits Developmental Pathways for Health Research Unit (DPHRU) at Chris Hani Baragwanath Academic Hospital (CHBAH) in Soweto. CHBAH is a public tertiary care institution that provides medical services to the low-income community of Greater Soweto, located in the southwestern area of Johannesburg, South Africa. It is one of the largest hospitals in the world. The peri-urban neighbourhood of Soweto is well known for its established communities, as well as the socioeconomic and cultural diversity that can be found there. We adopted a longitudinal design for our research. The following were the selection criteria for the participants who were part of the study: (i) adolescent boys (n = 125) and girls (n = 125) aged 13–17 years, all of whom needed to be accompanied by their parent/caregiver and who resided in Soweto; (ii) young adult males (n = 125) and females (n = 125) aged 27 years old; and (iii) middle-aged men (n = 125) and women (n = 125) aged 45^{+} years. A random sampling of households in Soweto was conducted to recruit 250 adolescent participants. In addition, the purposeful selection of 250 young adults who participated in the "Birth to Twenty" cohort study and 250 middle-aged adults from the "Determinants for Type 2 Diabetes Mellitus (T2D)" study was used to obtain 500 adult participants. In

total, 750 self-identified black South Africans agreed to take part in the study after being recruited. Before taking part in the study, each participant first provided his or her informed consent in written form. The Human Research Ethics Committee (HREC) of Witwatersrand University, with ethics numbers M170663 and M160604, granted ethical approval (Figure 1).

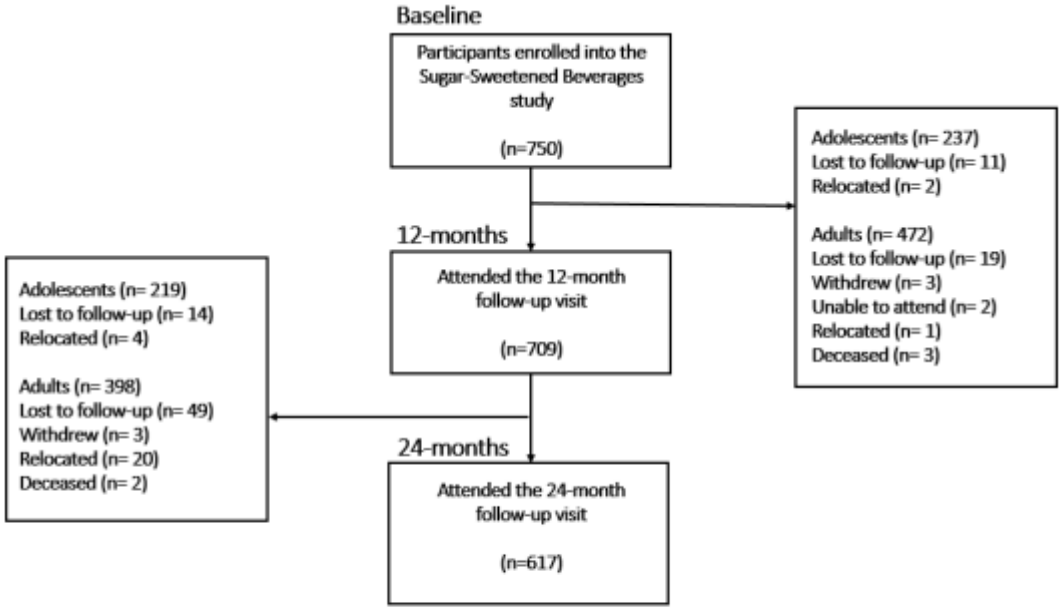

Figure 1. Diagrammatic representation of the flow of participants in the study.

Following the recruiting and enrolling of the adults and adolescents in the study, all of the data were collected at the SAMRC/Wits DPHRU site using the same methodology. May 2017 marked the beginning of the collection of the baseline data. After 12 months, and then again after 24 months, the participants returned to the DPHRU for follow-up visits.

2.2. *Dietary Intake Assessment*

Dietary intake was estimated using a seven-day quantitative food frequency questionnaire (QFFQ), with 214 commonly consumed foods taken from the analyses of eleven dietary surveys conducted in rural and urban South Africa since 1983 [36,37]. Furthermore, this tool has also been piloted and utilised extensively in Soweto, as described elsewhere [38–40]. To complete the QFFQ, trained research assistants used high-quality photographs of food items to trigger participants' memories of all foods and beverages consumed during the previous seven days. The participants were asked to arrange the cards into three piles: foods eaten in the last seven days; foods eaten occasionally; or foods never consumed, and this was recorded. The QFFQ was then administered and took approximately 40–50 min to complete. In the case of food items consumed in the past seven days, additional data on the frequency and quantity of consumption was recorded. Portion sizes were estimated using a combination of high-quality two-dimensional drawings of foods, household utensils and three-dimensional food models, which have been described and validated by Steyn et al. [37]. The estimated portion sizes were converted to grams to allow for the calculation of the participant's average intake over the previous seven days. The QFFQ was captured and managed online using the REDCap electronic data capture tools hosted at The University of the Witwatersrand [41]. The nutrient composition (energy and macronutrients) was calculated from the conversion of the single food item intakes by

the SAMRC using the South African Food Composition Tables. Over- and under-reporting of dietary intake was corrected by removing the participants with total energy intake <3000 and >30,000 kJ, as described by Vorster et al. [42].

2.3. Demographic Questionnaires

The Demographic and Health Surveys household questionnaire (available at: www.measuredhs.com; accessed on 1 May 2017), which has been extensively utilised in this setting, was used to collect the participant socio-demographic variables [43,44]. An asset index was used to score each participant according to the number of assets they possessed out of a possible 12 (electricity, radio, television, refrigerator, mobile phone, personal computer, bicycle, motorcycle/scooter, car, agricultural land and farm animals). This was conducted so that the socio-economic status of the household could be determined.

2.4. Anthropometry

A Holtain, UK, stadiometer was used to measure their height in millimeters (mm), and those readings were then converted to meters (m). Utilizing a portable electronic bathroom scale, their exact weight was determined down to the nearest 0.1 kg (kg) (Seca Gmbh & Co. KG, Hamburg, Germany). All of the participants were asked to remove their shoes and wear light clothing for the measurement. The body mass index (BMI) was determined by dividing a person's weight in kilograms by their height in meters squared (kg/m^2).

2.5. Data Analysis

Both Stata SE version 17 and the statistical package for social scientists (SPSS) version 26 were utilised in the compilation and interpretation of the statistical findings. Q-Q plots were utilised in the process of conducting normality tests on the continuous variables. The daily macronutrient intakes of the study participants, both adolescents and adults, were characterised through the application of descriptive statistics. Twenty-five nutrients were used to derive the nutrient patterns via principal component analysis (PCA), as described by Pisa et al. [28]. Additionally, from the 25 nutrients, the total protein was split into animal protein and plant protein; the total carbohydrates were divided into total sugar, starch and total dietary fibre. The total fat was categorised into saturated fat, monounsaturated fat and polyunsaturated fat [29]. The total dietary fibre comprised of soluble and insoluble dietary fibre. To remove bias due to variance caused by the different measures of scale used to quantify the nutrients, we log-transformed the nutrient intake variables from the QFFQ [29]. The nutrient density method was used to adjust the total energy intake [35]. PCA was performed with the variance based on the correlation matrix and varimax rotation. We used the scree plot (Figure 2) to determine the number of PCs to retain (Figures 2 and 3), which we indicated as the nutrient patterns. The nutrients with loadings greater than ± 0.47 on the PCs were used to name the nutrient patterns [29]. In order to determine the significance of the extracted PCs, the total variances that were explained by the retained PCs were also analysed and evaluated. Both the Kaiser–Meyer–Olkin measure of sampling adequacy, which was 0.911, and Bartlett's test of sphericity, which was significant at $p < 0.001$, indicated that the principal component analysis (PCA) was an appropriate method for the data reduction approach used for the nutrient data in this study.

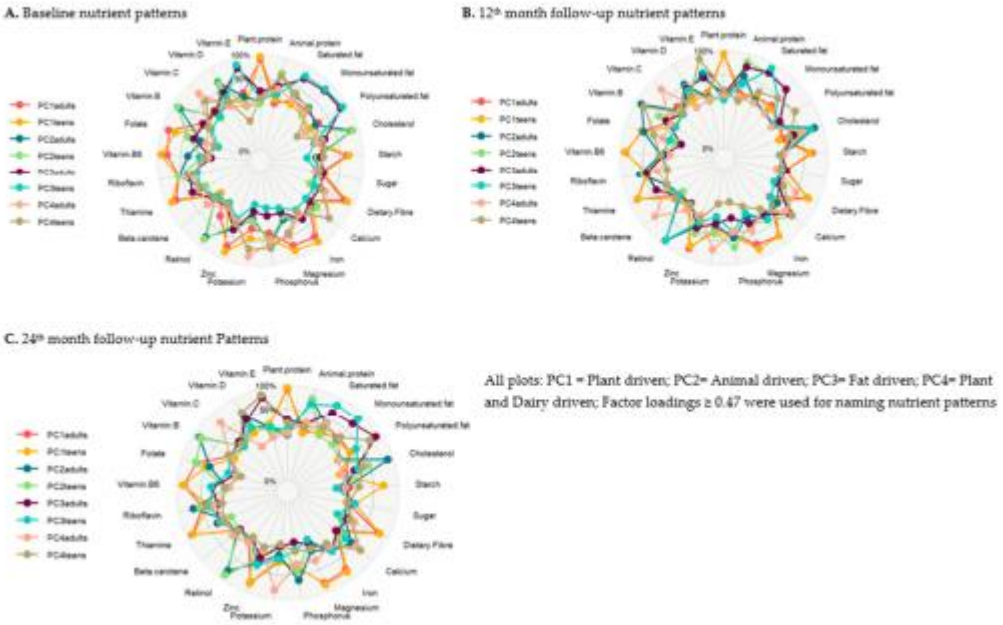

Figure 2. Nutrient patterns factor loadings showing the nutrients driving the nutrient patterns in black South African adults and teens.

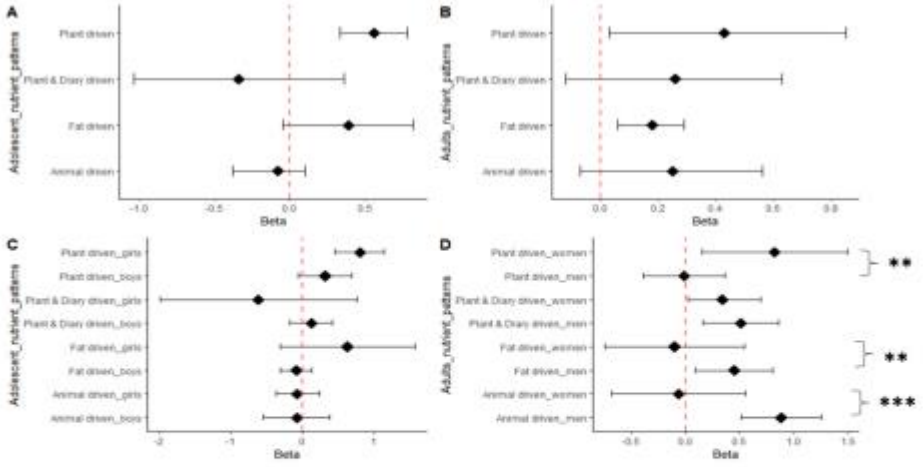

Figure 3. Sex differences in the association of nutrient patterns with BMI. (**A**). Nutrient pattern associations of nutrient patterns with BMI in SA adolescent boys and girls. (**B**). Nutrient pattern associations of nutrient patterns with BMI in SA men and women. (**C**). Sex–stratified nutrient patterns in adolescents. A significant sex*plant–driven nutrient pattern on BMI was noted at ($p < 0.05$). (**D**). Sex–stratified nutrient patterns in adults. All associations are adjusted for age, gender, household socio-economic status and energy intake reporting. A significant sex*plant–driven nutrient pattern on BMI was noted at ** ($p < 0.01$), the sex*animal–driven nutrient pattern on BMI was noted at *** ($p < 0.001$) and the sex*fat–driven nutrient pattern on BMI was noted at ** ($p < 0.01$).

Generalised estimating equations (GEE) regression models were computed separately for the adults and adolescents to assess the association between BMI as the dependent variable. In contrast, the nutrient patterns, household socioeconomic status (SES), gender, age, the estimated energy intake and estimated energy requirements (EI/EER) ratio (EI/EER), which is an indicator of the plausibility of dietary energy intake reporting, and the general energy efficiency index were used as predictors. The EI/EER ratio [45] was determined using the following Institute of Medicine (IOM) energy expenditure equations (EER).

Girls (9–18 years); EER = 88.5 − (61.9 × age [y]) + PA × (26.7 × weight [kg] + 903 × height [m]) + 25 kcal)

Boys (9–18 years); EER = 135.3 − (30.8 × age [y]) + PA × (10.0 × weight [kg] + 934 × height [m]) + 25 kcal)

Men (19 years and older); EER = 662 − (9.53 × age [y]) + PA × (15.91 × weight [kg] + 539.6 × height [m])

Women (19 years and older); EER = 354 − (6.91 × age [y]) + PA × (9.36 × weight [kg] + 726 × height [m])

To catergorise the plausible reporters (0.7–1.42), under-reporters (<0.7) and over-reporters (>1.42), the EI/EER ratio was used [46].

3. Results

3.1. Descriptive Characteristics of the Study Population

The median BMI level was 20.1 (18.2; 22.8) kg/m^2 for the adolescents and 26.6 (22.2; 32.7) kg/m^2 for the adults. The adult women's median BMI of 29.1 (23.7; 36.1) kg/m^2 signified that a considerable proportion of the women were overweight. Overall, the adolescent boys had the highest total energy intake, with 11,305 (8709; 14,153) KJ, and consumed higher amounts of plant protein 35.9 (27.6; 48.3) and carbohydrates 366.0 (282.4; 436.7) g/day than the other groups. The boys and girls differed significantly ($p < 0.05$) in terms of their BMI, height, fat, carbohydrate and EI/EER ratio. Furthermore, the weight, height, BMI, total energy, total protein, total fat, saturated fat, mono and poly unsaturated fat and added sugar were significantly different between the men and women ($p > 0.05$). With that said, the adolescent girls had higher intakes of total fat, 100.8 (73.9; 144.6) g/day, while the adults had higher intakes of animal protein, 34.6 (24.5; 48.5) g/d, compared to other groups, as indicated in (Table 1).

3.2. Nutrient Patterns

Four similar nutrient patterns were extracted at the baseline visit, 12 month follow-up and 24 month follow-up from the principal component analysis among the peri-urban adolescents and adults; these patterns were named according to the nutrients with the highest factor loadings, as indicated in Figure 3. The four nutrient patterns cumulatively explained 71.50% and 69.04% at baseline, 66.03% and 64.62% at the 12 month follow-up and 61.15% and 64.90% at the 24 month follow-up of the total variance in the adolescents and among the adults, respectively.

For adolescents and adults, the first PC retained had higher loadings of plant protein, starch, dietary fibre, iron, magnesium, zinc, vitamin B6, riboflavin, thiamine and folate over the 24 months. It was named "Plant-driven nutrients". The second PC was named "animal-driven nutrients" because it had high positive loadings of vitamin B12, vitamin D, cholesterol, phosphorus, riboflavin, animal protein, phosphorus, calcium, retinol, saturated fat, monounsaturated fat and folate over the 24 months. The third PC was named "fat-driven nutrients". This nutrient pattern had high positive loadings of saturated fat, monounsaturated fat, polyunsaturated fat, cholesterol, retinol, animal protein and vitamin E. The fourth extracted PC had high loadings of animal protein, calcium, potassium, phosphorus, monounsaturated fat, polyunsaturated fat, vitamin B12, vitamin E, vitamin D and vitamin C. As a result of these positive loadings, this nutrient pattern was named "Plant and Dairy-driven nutrients" (Figure 3). Factor loadings ≥ 0.47 were used for naming the nutrient patterns.

Table 1. Descriptive characteristics for adolescents and adults.

	Adolescents				Adults			
	Total (n = 250)	Median (IQR) Male (n = 125)	Female (n = 125)	p-Value [a] (M vs. F)	Total (n = 500)	Median (IQR) Male (n = 250)	Female (n = 250)	p-Value [a] (M vs. F)
Age (year)	14 (13; 15)	14 (14; 15)	14 (13; 15)	0.222	27 (27; 52)	35 (27; 55)	27 (27; 50)	0.053
Weight (kg)	52.6 (46.6; 59.8)	51.9 (44.6; 58.4)	53 (48; 60.6)	**0.012**	72.5 (60.5; 84.8)	70.5 (59.4; 81.2)	74.7 (62.8; 74.7)	**0.002**
Height (m)	1.60 (1.54; 1.66)	1.63 (1.55; 1.69)	1.57 (1.53–1.62)	**<0.001**	1.64 (1.58; 1.71)	1.68 (1.62; 1.73)	1.61 (1.56; 1.66)	**<0.001**
BMI (kg/m^2)	20.1 (18.2; 22.8)	19.3 (17.7; 21.1)	21.3 (19.2; 24.6)	**<0.001**	26.6 (22.2; 32.7)	25.1 (21.2; 28.8)	29.1 (23.6; 35.8)	**<0.001**
Total energy (kJ/day)	11,123 (8437; 14,284)	11,305 (8709; 14,153)	11,042 (8234; 14,705)	0.878	9438 (6258; 14,686)	9955 (6756; 15,799)	8720 (5960; 12,284)	**0.001**
Total protein (g/day)	65.6 (49.7; 86.3)	68.9 (49.8; 88.3)	64.3 (49.4; 83.9)	0.227	63.2 (42.7; 90.9	67.4 (48.1; 96.6)	55.4 (38.0; 82.2)	**0.025**
Plant protein (g/day)	34.3 (25.6; 47.4)	35.9 (27.6; 48.3)	33.3 (24.7; 45.7)	**0.010**	27.4 (18.5; 41.9)	30.9 (19.5; 45.6)	24.9 (17.9; 36.6)	**0.013**
Animal protein (g/day)	29.5 (18.9; 41.8)	29.8 (18.5; 39.9)	29.5 (19.2; 43.3)	0.842	31.1 (19.4; 48.0)	34.6 (24.5; 48.5)	27.6 (17.5; 45.7)	0.318
Total fat (g/day)	97.2 (70.9; 142.9)	95.7 (70.4; 134.6)	100.8 (73.9; 144.6)	**0.024**	85.6 (50.6; 135.1)	86.7 (51.4; 139.0)	84.2 (50.5; 130.3)	**<0.001**
SFA (g/day)	24.1 (16.9; 35.1)	23.2 (16.6; 33.6)	24.9 (17.2; 36.9)	**0.010**	21.6 (13.3; 33.9)	21.5 (13.8; 34.9)	20.5 (12.7; 33.3)	**<0.001**
MUFA (g/day)	28.7 (19.1; 41.1)	28.7 (19.1; 39.6)	28.7 (19.1; 42.5)	0.468	21.8 (15.7; 40.9)	26.87 (16.9; 40.8)	24.9 (15.2; 40.9)	**0.002**
PUFA (g/day)	32.9 (20.1; 49.5)	33.1 (20.3; 47.4)	32.8 (20.1; 53.9)	0.109	24.1 (14.9; 40.9)	25.3 (15.0; 42.3)	22.5 (14.9; 39.4)	**0.003**
Carbohydrate (g/day)	352.3 (257.6; 436.6)	366.0 (282.4; 436.7)	341.3 (249.5; 433.5)	**0.031**	284.4 (187.4; 416.1)	315.3 (194.9; 465.9)	264.3 (183.2; 366.4)	0.460
Added sugar (g/day)	70.7 (44.0; 113.2)	70.6 (45.9; 117.8)	70.9 (42.6; 106.6)	0.227	56.6 (32.1; 95.9)	55.4 (28.9; 101.6)	59.4 (35.7; 88.4)	**0.004**
EI/EER ratio (kJ/day)	1.18 (0.88; 1.51)	1.11 (0.82; 1.39)	1.31 (0.96; 1.70)	**0.007**	1.003 (0.64; 1.54)	1.06 (0.64; 1.72)	0.96 (1.34; 0.65)	0.161

Significant results presented in bold ($p < 0.05$); [a] t-test; BMI = Body Mass Index; IQR = Interquartile range; SFA = Saturated fat; MUFA = Monounsaturated fat; PUFA = Polyunsaturated fat; EI-EER = Estimated energy intake and estimated energy requirements.

3.3. Nutrient Pattern Associations with BMI

The association results of the extracted nutrient patterns and BMI are shown in Figure 3 and Supplementary File (Tables S1–S6) for the peri-urban adolescents and adults. A standard deviation change in the "Plant-driven nutrients pattern" was significantly associated with a 0.56 kg/m^{-2} (95% CI (0.33; 0.78); $p = 0.000$ increase in BMI among the adolescents, as shown in Figure 3A. There was a significant sex*plant-driven nutrient pattern interaction for BMI, with the association being significant in adolescent girls only (0.81 kg/m^{-2} (95% CI: 0.46; 1.15) $p = 0.054$) as illustrated in Figure 3C. Among the adults, the "plant-driven nutrient pattern" and the "fat-driven nutrient pattern" were associated with an increase in BMI, as illustrated in Figure 3B. A standard deviation change in the "plant-driven nutrient pattern" was significantly associated with 0.43 kgm^{-2} (95% CI (0.03; 0.85); $p = 0.000$), and the "fat-driven nutrient pattern" was significantly associated with a 0.18 kgm^{-2} (95% CI (0.06; 0.29); $p = 0.000$) increase in BMI for all of the adults. Further analysis revealed that there was a significant sex*plant-driven nutrient pattern interaction for BMI, with the association being significant in the women (0.34 kg/m^{-2} (95% CI: 0.03; 0.69) $p = 0.011$), and a considerable sex*animal-driven nutrient pattern interaction and sex*fat-driven nutrient pattern interaction for BMI, with the association being significant in the men (0.88 kgm^{-2} (95% CI (0.51; 1.25)) $p = 0.000$) and (0.45 kgm^{-2} (95% CI (0.09; 0.80)); $p = 0.013$), as shown in Figure 3D, respectively.

4. Discussion

We set out to identify and compare the nutrient patterns changes in black South African adolescents and adults over a period of 24 months, and to assess how these changes are associated with the participants' body mass index. At baseline, the extracted nutrient patterns explained 71.50% and 69.04% of the total variance in the adolescent and adult nutrient intakes, respectively; at the 12 month follow-up, they explained 66.03% and 64.62%; and at the 24 month follow-up, they explained 61.15% and 64.90%. While the nutrient patterns of the adolescents and adults were comparable over time, their associations with BMI were distinct. Only the "plant-driven nutrients pattern" was significantly and positively associated to an increase in BMI of 0.56% (95% CI (0.33; 0.78); $p < 0.001$) in the adolescents. Among the adults, both the "plant-driven nutrient pattern" (0.43% (95% CI (0.03; 0.85); $p < 0.001$) and the "fat-driven nutrients pattern" (0.18% (95% CI (0.06; 0.29); $p < 0.001$) were significantly and positively associated with an increase in BMI. Additionally, sex differences in the associations of the "plant-driven nutrient pattern", "fat-driven nutrient pattern" and "animal-driven nutrient pattern" with BMI were observed. Notably, the "plant-driven nutrient pattern" and BMI had a positive and significant relationship in the adolescent girls and women, but a negative and non-significant relationship in the adolescent boys and men. In contrast, only in the men, compared to the women, were the animal- and fat-driven nutrient patterns more positively and significantly associated with BMI.

To the author's knowledge, no studies have evaluated the longitudinal association between nutrient patterns and BMI in black South African adolescents and adults. According to the findings of our study, urban adolescents of both sexes consume a diet that is predominantly plant-based in terms of its nutrient composition. On the contrary, Pisa et al. (2015) [28] found that adolescents in rural areas consumed "animal-derived nutrients" the most. This implies that the dietary habits of adolescents are affected by their location and socioeconomic status (urban versus rural), and interventions designed to promote healthier dietary choices should consider this before they are put into action. Findings from other research studies shows that rural areas are undergoing a rapid transition in nutrition [28,47,48], which is accompanied by lower levels of physical activity [48,49], especially in teenage girls. As a result, higher intakes of animal protein, fat and added sugar have been observed [28,50,51], showing a shift to a more "western" diet [49], which further supports the disparity between the results of the current study and those of Pisa et al. [28] among adolescents. Despite this, the adult nutrient patterns presented in this study, which show that plant-based nutrients are consumed the most, are consistent with those reported by

Ratshikombo et al. [23] among middle-aged men and women and by Makura-Kankwende et al. [31,32] among middle-aged women residing in urban South Africa. The implication that the patterns presented in this study are similar to those presented in earlier studies on adults [30–32] is due to the reason that all of these studies were conducted on urban-dwelling adults, which suggests that the nutrient patterns among adults who live in cities are applicable to a broad range of communities. Furthermore, the differences in nutrient patterns intake between rural and urban adolescents, and the similarities between urban adolescents and adults, reveals that city dwellers have different nutrient intake patterns than rural residents. Consequently, this also implies that the nutrient patterns of urban and rural dwellers will vary in their relation to body mass index. This variation highlights the need to factor in the impact of context on individuals' nutrient patterns when designing interventions.

A comparison of the nutrient patterns of adults and adolescents was carried out, and our findings revealed that the patterns remained constant over the course of the two years that the research was carried out, with the plant-based nutrient pattern being the one that was consumed the most overall. This consistency and similarity demonstrates that urban households consume diets that contain foods that are comparable to one another, and it lends support to the finding that the plant-based nutrient pattern is the one that is most consumed in urban South Africa [23]. However, as a result of the adolescents' low BMI, which made it difficult to detect associations at a young age, we also observed that the relationship between nutrient patterns and BMI was more pronounced in the men and women than in the boys and girls. However, given the similarities of the nutrient patterns between the adults and adolescents in this study over time, the nutrient patterns of urban dwellers can be generalised regardless of age. Furthermore, because of their consistency and homogeneity over time, interventions to promote healthy dietary intake can begin in adolescence and continue into adulthood. The results of this study lend credence to the idea that adolescence is an important period in which to encourage health-friendly changes in behaviour in order to enhance both short-term and long-term health outcomes and ease the burden to our health system [51].

Noteworthy gender differences were observed in the association between nutrient patterns and BMI. The plant-driven pattern's association with BMI varied by sex, with women showing a stronger association than men. This is consistent with previous cross-sectional findings in urban men and women [30]. Interestingly, our findings show that this relationship emerges during adolescence, with the adolescent girls in the present study also showing a significant association between the plant-driven pattern and BMI, a previously unknown finding. On the contrary, the association between animal-driven and fat-driven nutrient patterns and BMI was found to be stronger in men than in women A finding that is similar to that reported in previous cross-sectional research [30]. This is also in line with reports on black households in South Africa, which found that male dietary needs are given higher priority than those of women and children, especially when it comes to meals that contain high amounts of protein, such as meat-based meals [44]. Most importantly, these associations point to a shift toward westernised diets that are high in energy-dense foods [43,44]. In turn, this means that men have a higher risk of developing non-communicable diseases than women.

The current study's strengths are its longitudinal design, the use of a validated and comprehensive QFFQ and the assessment of nutrient patterns in both adolescents and adults. Longitudinal nutrient evaluation has several benefits, including the ability to identify stability and compare similarities between adolescents and adults. Despite the subjective nature of the pattern interpretation and labelling, the PCA technique is well-established for capturing real-life dietary behaviours [28,29]. One limitation of our study was that we did not collect data on the participants' levels of physical activity beyond what was captured by the QFFQ. However, the EI/EER ratio was used to adjust the participants' self-reported energy intake in order to reduce dietary reporting bias. Furthermore, it is not possible to generalise or extrapolate the relationships shown between nutrient patterns and

BMI to people living in rural areas because the data presented are restricted to urban areas only. As a consequence of this, investigations are required consisting of data gathered from both urban and rural areas.

5. Conclusions

To conclude, the nutrient patterns of urban adolescents and adults are comparable, and while there are age and gender differences in their association with BMI, their consistency over time suggests that nutrition interventions aimed at improving health outcomes can start earlier, in adolescence. The current findings highlight the significance of taking gender differences into account and the significance of addressing both girls' and boys' health-related behaviours, which has implications for future efforts to improve preconception health through nutrition. They can serve as a starting point for developing nutrition interventions that aim to address the health needs of adolescents and, in turn, address the issue of maternal and child mortality, as well as prevent the risk of chronic diseases in adulthood and future generations. Moreover, our findings provide insightful data that can be used monitor progress and help revise the current South African Strategy for the Prevention and Control of Obesity (2015–2020). Our recommendation is that future longitudinal studies examine the relationship between the nutrient patterns and body mass index of rural residents in order to gain a deeper understanding of their dietary behaviour and ensure no one is left behind, as the current study only examined urban residents. By doing so, South Africa would make significant progress in battling obesity and chronic NCDs, as it will aid the development and implementation of national level interventions.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/nu15051075/s1. Nutrient patterns associations with body mass index (BMI) (Table S1–S6). Table S1. Longitudinal associations of nutrient patterns and BMI in adolescents. Table S2. Longitudinal associations of nutrient patterns and BMI in adults. Table S3. Longitudinal associations of nutrient patterns and BMI in girls. Table S4. Longitudinal associations of nutrient patterns and BMI in boys. Table S5. Longitudinal associations of nutrient patterns and BMI in women. Table S6. Longitudinal associations of nutrient patterns and BMI in men.

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Institutional Review Board Statement: This study was conducted according to the guidelines laid down in the Declaration of Helsinki, and all procedures involving human participants were approved by the University of the Witwatersrand's Human Research Ethics Committee (HREC; ethical clearance numbers M170663 and M160604).

Informed Consent Statement: All participants gave written informed consent prior to taking part in the study.

Data Availability Statement: The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

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