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EXPLORING THE PARADOX:

Double burden of malnutrition in rural South Africa

by

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A THESIS

Submitted to the School of Public Health, Faculty of Health Sciences, University of the Witwatersrand, in fulfilment of the requirements for the degree

of

Doctor of Philosophy

JOHANNESBURG, SOUTH AFRICA

2010













Declaration

I, Elizabeth Wambui Kimani declare that this thesis is my original work. Where there has been contribution from other people, this has been duly acknowledged. It is being submitted for the degree of Doctor of Philosophy in Public Health in the University of the Witwatersrand, Johannesburg, South Africa. It has not been submitted before for any degree or examination at this or any other University.

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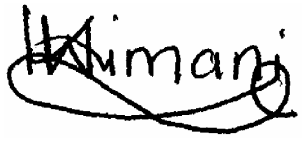
Signature:  Date: 14.10.2010

Dedication

I dedicate this work to my family: to you Martin for your undying support and commitment through the PhD period, and for your endurance during the lonely moments; to you Kito for enduring the "motherless" moments. I dedicate it to Nyambura, for lovingly taking care of my family, particularly my baby Kito during the long periods of my absence. I dedicate it to you mum; your constant encouraging words when I was young "Gûtirî kîega kiumaga hega" (nothing good comes along easily), and your assurance of daily prayers for me throughout the PhD period kept me going, even during difficult moments. I dedicate it to you dad, your dream of seeing me pursue my studies to the highest level were lived in your lifetime. For your love and support, I dedicate it to you all!

Original Papers

I. Kimani-Murage E, Kahn K, Pettifor J, Tollman S, Dunger D, Gomez-Olive X, Norris S. The prevalence of stunting, overweight and obesity, and metabolic disease risk in rural South African children. BMC Public Health2010;10(1):158.

Student's contribution to the paper

Design of the study, project implementation and management (including supervision of data collection), data management including cleaning, data analysis and writing of the manuscript

II. Kimani-Murage EW., Norris S.A., Pettifor J.M., Klipstein-Grobusch K., Tollman S.M., Gómez-Olivé F.X., Dunger D.B., Kahn K. Nutritional status and HIV in rural South African children (Submitted, BMC paediatrics Journal)

Student's contribution to the paper

Design of the study, project management, training and supervising fieldworkers, data management including cleaning, data analysis and writing of the manuscript

III. Kimani-Murage EW, Manderson L, Norris SA, Kahn K. 'You opened our eyes': care-giving after learning a child's positive HIV status in rural South Africa. Health and Social Care in the Community (2010) 18(3), 264–271.

Student's contribution to the paper

Design of the study, seeking partial funding for the project grant, project management (including training fieldworkers and supervision of data collection), data management including cleaning and coding, data analysis and writing of the manuscript

IV. Kimani-Murage EW. Kahn K, Pettifor JM, Tollman SM, Klipstein Grobusch K, Norris SA. Predictors of adolescent weight status and central obesity in contemporary rural South Africa (Submitted, Journal of Adolescent Health)

Student's contribution to the paper

Design of the study, project management, training and supervising fieldworkers, data management including cleaning and analysis, writing of the manuscript

Conference Proceedings

I. Kimani-Murage E.W., Norris S.A., Pettifor J.M., Klipstein-Grobusch K., Tollman S.M., Gómez-Olivé F.X., Dunger D.B., Kahn K. Patterns of malnutrition among 1-4 year children by HIV status and covariates of malnutrition in rural South Africa. Oral presentation at the INDEPTH AGM, 26-29th October, 2009, Pune, India.

II. Kimani-Murage E.W, Manderson L, Norris S.A., Kahn K. "You opened our eyes": Caregiving after learning a child's positive HIV status in rural South Africa. Oral presentation at the INDEPTH AGM, 26-29th October, 2009, Pune, India.

III. Kimani-Murage EW., Kahn K., Pettifor J.M., Tollman S.M. Goméz-Olivé F.X., Dunger D., Norris S.A. Age & sex patterns of the coexistence of under & over-nutrition in children and adolescents in contemporary rural South Africa. Distinguished poster presentation at the 19th International Congress of Nutrition (ICN), 4-9th October 2009, Bangkok, Thailand.

IV. Kimani-Murage E.W., Norris S.A., Pettifor J.M., Klipstein-Grobusch K., Tollman S.M., Gómez-Olivé F.X., Dunger D.B., Kahn K. Malnutrition Patterns by HIV Status for 1-4 Year Olds in Rural South Africa. Oral presentation at the Population Association of Southern Africa (PASA) conference, 8-10th July 2009, Cape Town, South Africa.

V. Kimani-Murage EW, Manderson L, Norris SA, Kahn K. "You opened our eyes": Caregiving

after learning a child's positive HIV status in rural South Africa. Oral presentation at the Population Association of Southern Africa (PASA) conference, 8-10th July 2009, Cape Town, South Africa.

VI. Kimani-Murage EW., Kahn K., Pettifor J.M., Tollman S.M. Goméz-Olivé F.X., Dunger D., Norris S.A. Coexisting under- & over-nutrition in rural South Africa. Oral presentation at the Biennial Wits School of Public Health Research Day, 14th May, 2009, Wits University, Johannesburg, South Africa.

VII. Kimani-Murage E.W., Kahn K., Pettifor J.M., Tollman S.M. Goméz-Olivé F.X., Dunger D., Norris S.A. Age & sex patterns of the coexistence of under & over-nutrition in rural South Africa. Oral presentation at the 1st Wits Cross-Faculty Symposium, 7-8th November 2008, Wits University, Johannesburg, South Africa.

VIII. Kimani-Murage E.W., Kahn K., Pettifor J.M., Tollman S.M. Goméz-Olivé F.X., Norris S.A. The paradox continues: evidence of coexisting under- & over-nutrition in rural south Africa. Oral presentation at the 4th Public Health Association of South Africa (PHASA) 2008 conference, 2-4th June 2008, Cape Town, South Africa.

Awards

Fellowships

1. PhD Fellowship by the Flora and William Hewlett Foundation through the University of the Witwatersrand, South Africa, 2007-2010.

2. Short Training Fellowship: African Nutrition Leadership Program (ANLP) 10-17 March 2009, hosted by North West University, South Africa.

Research Grants

3. Small grant from the Medical Faculty Endowment Fund, University of the Witwatersrand, South Africa for partial funding of my PhD research project in Agincourt, Bushbuckridge, South Africa, 2008.

Recognition Awards

4. Award for outstanding poster presentation at the XXVI International Population Conference of the International Union of Scientific Study of Population (IUSSP), 27th Sep-2nd October 2009, Marrakech Morocco

5. Award for outstanding oral presentation at the 4th Public Health Association of South Africa (PHASA) conference, 2-4 June 2008, Cape Town, South Africa.

Travel Awards

7. Young Scientist Award to attend the 9th INDEPTH Conference, 26-29th October 2009, Pune, India.

8. Travel Award to the 8th International Conference on Urban Health, 18-23th October 2009, Nairobi, Kenya

9. Travel Award to the 19th International Congress of Nutrition (ICN), 4-9th October 2009th, Bangkok, Thailand

10. Travel award to the 4th Public Health Association of South Africa (PHASA) 2008 conference, 2-4th June 2008, Cape Town, South Africa.

11. Young Scientist Award to attend the 8th INDEPTH Conference, 22-26 September 2008, Dar es Salaam, Tanzania.

12. Travel award to the 5th Union of African Population Studies (UAPS) Conference, 10th to 14th December 2007, Arusha, Tanzania.

Abstract

Background: In low- to middle-income countries, rising levels of overweight and obesity are a result of multiple transitions, in particular, a nutrition transition. Consequently, in these countries, metabolic diseases are contributing increasingly to disease burden, despite the persisting burden of undernutrition and infectious diseases. Understanding the patterns and factors associated with persistent undernutrition and emerging obesity in children and adolescents, and concomitant risk for metabolic disease, is therefore of criticial importance. This should contribute to public health policy on interventions to prevent adult disease.

Aims: To better understand the double burden of malnutrition in a poor, high HIV prevalent, transitional society in a middle-income country; In so doing, to inform policies and interventions to address the double burden of malnutrition.

Methods: A cross-sectional growth survey was conducted in 2007 targeting 4000 children and adolescents 1-20 years of age living in rural South Africa. The survey was nested within the ongoing Agincourt Health and Socio-demographic Surveillance System, which acted as the sampling frame and also provided data for explanatory variables. Anthropometric measurements were performed on all participants using standard procedures. In addition, HIV testing was done on children aged 1 to 5 years and Tanner pubertal assessment was conducted among adolescents 9-20 years. A one-year follow-up of HIV positive children included a matched control group of HIV negative counterparts. Data collection involved both quantitative and qualitative methods. Growth z-scores were used to determine stunting, underweight and wasting and were generated using the 2006 WHO growth standards for children up to five years and the 1977 NCHS/WHO reference for older children. Overweight and obesity were determined using the International Obesity Task Force cut-offs for BMI for children aged up to 17 years and adult cut offs of BMI =25 and =30 kg/m^2 for overweight and obesity respectively for adolescents 18 to 20 years. Waist circumference cut-offs of =94cm for males and =80cm for females, and waist-to-height ratio of 0.5 for both sexes, were used to determine central obesity and hence metabolic disease risk in

adolescents. Descriptive analysis described patterns of nutritional status by age, sex, pubertal stage and HIV status. Linear and logistic regression was done to determine predictors of nutrional outcomes. A p-value of <0.05 was considered statistically significant.

Results: Prevalence of undernutrition, particularly stunting, was substantial: 18% among children aged 1-4 years, with a peak of 32% in children at one year of age. Stunting and underweight were also substantial in adolescent boys, with underweight reaching a peak of 19% at 14 years of age. Concurrently, the prevalence of combined overweight and obesity, almost non-existent in boys, was prominent among adolescent girls, increasing with age, and reaching a peak of 25% at 18 years. Risk for metabolic disease using waist circumference cut-offs was substantial among adolescents, particularly girls, increasing with sexual maturation, and reaching a peak of 35% at Tanner stage 5. Prevalence of HIV in children aged 1-4 years was 4.4%. HIV positive children had poorer nutritional outcomes than that of HIV negative children in 2007. The impact of paediatric HIV on nutritional status at community level was, however, not significant. Significant predictors of undernutrition in children aged 1-4 years, documented at child, maternal, household and community levels, included child's HIV status, age and birth weight; maternal age; age of household head; and area of residence. Significant predictors of overweight/obesity and risk for metabolic disease in adolescents aged 10-20 years, documented at individual/child and household levels included child's age, sex and pubertal development; and household-level food security, socio-economic status, and household head's highest education level. There was a high acceptance rate for the HIV test (95%). One year following the test, almost all caregivers had accepted and valued knowing their child's HIV status, indicating that it enhanced their competency in caregiving. Additionally, nutritional status of HIV positive children had improved significantly within a year of follow-up.

Conclusions: The study describes co-existing child stunting and adolescent overweight/obesity and risk for metabolic disease in a society undergoing nutrition transition. While likely that this profile reflects changes in nutrition and diet, variation in infectious disease burden, physical

activity patterns, and social influences need to be investigated. The findings are critical in the wake of the rising public health importance of metabolic diseases in low- to middle-income countries, despite the unfinished agenda of undernutrition and infectious diseases. Clearly, policies and interventions to address malnutrition in this and other transitional societies need to be double-pronged. In addition, gender-biased nutritional patterns call for gender-sensitive policies and interventions. The study further documents a significant role of paediatric HIV on nutritional status, and the potential for community-based paediatic HIV testing to ameliorate this. Targeted early paediatric HIV testing of exposed or at risk children, followed by appropriate health care for infected children, may improve their nutritional status and survival.

Key Words: Nutrition transition, double burden of malnutrition, stunting, underweight, wasting, overweight, obesity, metabolic disease risk, HIV, rural, South Africa, low-to-middle income countries.

Acknowledgements

The value of this work is greatly owed to my supervisors Prof Kathleen Kahn and Prof Shane Norris. Thanks Kathy and Shane for your valuable guidance, support and commitment from the inception of this work to the completion. I have learnt a lot of things from you including outside academics. From you Kathy, most strikingly I have learnt meticulousness, succinctness and team work. From you Shane, most strikingly I have learnt hardwork and leadership: decision-making. You so well complemented each other. Thank you for your stimulation: for the friendly environment you created; without which the stresses of undertaking a PhD would have been unbearable. Thanks for being kind and concerned about my personal affairs; for allowing me flexi programme so as to spend reasonable time with my family back in Kenya. I am greatly indebted too to Prof Stephen Tollman, Prof John Pettifor, Prof Kerstin Klipstein-Grobusch, Prof Lenore Manderson, Prof David Dunger and Dr. Xavier Gómez-Olivé for their guidance particularly for reviewing my manuscripts and giving constructive comments; you all added great value to this work. Thanks to Edmore Marinda for technical assistance, Dr. Haroun Salooje and Ms Nicola Christofides for reviewing part of the work.

I highly appreciate funding for the PhD fellowship from the Flora and William Hewlett Foundation, USA, through the MRC/Wits Rural Public Health and Health Transitions Research Unit (Agincourt). Thank you Steve and Kathy for granting me the fellowship, and Linda Oldert for your efficient administration of the grant. I greatly appreciate funding for the fieldwork from the Wellcome Trust, UK, the National Research Foundation (NRF), the Medical Research Council (MRC) and the Faculty of Health Sciences (Faculty Endowment Fund), University of the Witwatersrand, South Africa.

I wholeheartedly appreciate technical and logistical support from the MRC/Wits-Agincourt Unit. Specifically, I thank Dr. Mark Collinson for his technical contributions to the design and

implementation of the studies from which my PhD data was derived, and for allowing me to use the Agincourt Health and Demographic Surveillance System data. I extend my heartfelt gratitude to the administration; the data management team; the data collection team; and the LinC office team for community mobilisation. Thank you Melta and everyone else at the Johannesburg MRC/Wits-Agincourt Unit for your great support. I am also highly indebted to data entry team from the Birth To Twenty programme, University of the Witwatersrand.

I most sincerely feel highly indebted to the African Population and Health Research Center (APHRC), Nairobi Kenya for technical and logistical support during the conceptualisation of the PhD to completion. Specifically, I am very grateful for the three year pre-doctoral Research Traineeship Programme which greatly prepared me for PhD studies. I would like to specifically thank the administration for logistical support and Dr. Alex Ezeh, Dr. Eliya Zulu, Dr. Francis Mugisha, Prof Nyovani Madise, Dr. Jean-Christophe Fotso, Dr. Chichi Undie, Dr. Yazoume Ye and Dr. Zewdu Woubalem for their great mentorship.

My heart-felt appreciation goes to my family; for patience, support and commitment from the inception of this work to completion. Thank you Martin for all the support and commitment you showed. Thanks too for staying awake for lengthy nights to ensure I finish planned work. Thanks too for technical advice on some issues related to the PhD work. Thanks Kito for your endurance; “will you come tomorrow” is a question you asked almost daily; you had to wait longer than normal for tomorrow to come…if it ever came. I am also highly indebted to Nyambura, who lovingly took care of my family while I was away. I am thankful to both my extended families, for dreaming on my behalf, for believing in me and their support throughout the PhD study period.

I sincerely thank my friends and colleagues, who gave me company and encouragement during my stay at Wits. I am most indebted to Tabither, Emily, Joy, Natsayi, Mary, Keegan, Akeem, Sophie

and many more. Without your warm friendship, my stay in South Africa would have been unbearable. On a more personal note, thank you Tabby for acting my little sister; for all your support.

This work would never have been if not for the kind volunteership of the study participants.

I owe it all to you!

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List of Abbreviations/Acronyms

AIDS	Acquired immune deficiency syndrome
ANOVA	Analysis of variance
ARV(s)	Antiretrovirals
ART	Anti-retroviral therapy/treatment
BMI	Body mass index
CD4	Cluster of Differentiation 4 (T-Helper Cells)
CDC	Centers for Disease Control
CI	Confidence interval
Cm	Centimetre(s)
CVD	Cardiovascular Diseases
DALYs	Disability-adjusted life years
DHS	Demographic and Health Survey
DoH	Department of Health
EGIR	European Group for the Study of Insulin Resistance
EST	Ecological Systems Theory
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
GEAR	Growth, Employment and Redistribution
GNP	Gross National Product
HAZ	Height-for-Age Z-scores
HDL	High Density Lipoprotein
HDSS	Health and socio-Demographic Surveillance System
HIV	Human Immunodeficiency Virus
IDF	International Diabetes Federation
IOTF	International Obesity Taskforce

Kg	Kilogram(s)
LDL	Low Density Lipoprotein
LINC	Learning, Information dissemination and Networking with Communities
LMICs	Low-to-Middle Income Countries
M	Metre(s)
MDG(s)	Millennium development goals
MGRS	Multicentre Growth Reference Study
MetS	Metabolic Syndrome
microL	Microlitre
MRC	Medical Research Council
NCEP ATP III	National Cholesterol Education Program—Third Adult Treatment Panel
NFCS	National food consumption survey
NCHS	National Center for Health Statistics
P	Probability
PhD	Doctor of Philosophy
PMTCT	Prevention of mother to child transmission of HIV
OR	Odds ratio
SAVACG	The South African Vitamin A Consultative Group
SD	Standard deviation
SES	Socio-economic status
TB	Tuberculosis
TG	Triglyceride(s)
TV	Television
UK	United Kingdom

UNICEF	United Nations Children's Fund
USA	United States of America
USD	United States dollar
VCT	Voluntary Counselling and Testing
WAZ	Weight-for-age z-scores
WHO	World Health Organization
WHtR	Weight-for-height ratio
WHZ	Weight-for-height z-scores
Wits	Witwatersrand
YRBS	Youth risk behaviour survey
ZAR	South African Rand

Preface

“We really are seeing the spread of a different form of malnutrition in the developing world and the globalisation of chronic diseases due to the adoption of energy-dense high-calorie diets, high in fat and sugars, and Western-style work and social infrastructures”.

Neville Rigby, director of policy and public affairs at the International Obesity Taskforce

"Sadly, it seems that we have somehow managed to bypass good health, moving from hunger to obesity in a single generation in many parts of the world,"

Marie Ruel, interim director of IFPRI's Food Consumption and Nutrition Division.

When I first thought of body of research towards a PhD, the subject of HIV came to my mind, as I thought that was what sub-Saharan Africa was, or ought to be most concerned about. Then I thought of what is traditionally known as malnutrition (undernutrition) in the context of high HIV prevalence. The thought of obesity did not cross my mind, as it did not seem an important problem in sub-Saharan Africa. It did not seem worth investing resources in obesity while the burden of disease due to undernutrition was still so enormous, at least in Kenya, my home country.

When I moved to South Africa to pursue PhD studies and reviewed literature guided by my supervisors, it dawned on me that the problem of malnutrition in South Africa was complex. First I was surprised at the rate of documented undernutrition that had persisted in South Africa since the days of Apartheid, despite South Africa transitioning into a middle-income country post-Apartheid. Then, literature on adult obesity, particularly in urban women, was striking. For example, according to the 2003 Demographic and Health Survey, about every second woman in South Africa was either overweight or obese, while on the other hand about every fourth child under five years was undernourished. It was difficult to understand how these two scenarios could coexist.

This encounter with literature, coupled with constant guidance by my supervisors, broadened my mind with regards to what I was going to explore in my PhD. I wondered, “How would the situation be, among children and adolescents in a rural setting, where the impact of HIV is so prevalent?” I thus moved on to develop a thesis protocol around nutrition transition in rural South Africa, with a special focus on children and adolescents up to 20 years of age.

This thesis presents a clear picture of the co-existence of high levels of stunting in early childhood with high levels of overweight and of obesity and the risk for metabolic disease in adolescent girls in a poor, HIV prevalent rural setting in South Africa. It opens a window on a disturbing trend in rural South Africa, presenting a multifaceted policy and programme challenge that calls for urgent evidence-based interventions.

This thesis adopts a modern style of thesis writing; the “thesis with publications style”, incorporating an integrating narrative with four journal articles. It is therefore divided into two parts: Part One is divided into six sections, presents the integrating narrative, synthesising the results of all the thesis papers in a holistic manner. Part Two presents the four papers of this thesis.

1.0 Introduction

A thorough literature review was done to identify the problem that exists, identify the gaps in literature and justify the need for the study. Both published and grey literature were reviewed. Various search engines were used to identify published literature including PubMed, Web of Science, Google Scholar and EBSCO Host. Google was also used to identify both published literature and non-published literature such as reports. Libraries also provided access to particularly grey literature including theses/dissertations, reports, and books. A list of key words and phrases were used in the literature search. These included malnutrition, undernutrition, stunting, underweight, wasting, overnutrition, overweight, obesity, double burden of malnutrition, nutrition transition, metabolic disease, HIV and malnutrition, physical activity, sedentary behaviour, causes/determinants of overweight/obesity and causes/determinants of malnutrition. The search was modified using defining/filtering key words such as low- and middle-income countries, developing countries, Africa, sub-Saharan Africa, low-resource settings, South Africa and rural areas.

1.1 Problem statement

A nutrition transition, that is, changes in diet composition commonly accompanied by changes in physical activity levels, is being experienced in low- to middle-income countries (LMICs) undergoing rapid economic transition and urbanisation. (1, 2) Nutrition transition refers specifically to a transition from traditional diets mostly derived from plant-based food sources requiring high labour intensity to produce, to high energy dense foods and a higher reliance on processed foods. The plant-based foods are low in fat and are high in fibre and their production is labour intensive. Modern high energy dense foods are on the other hand, high in fat and sugars, are often processed and prepared outside of the home requiring less labour. These dietary changes and decreased physical activity result in obesity-related problems and increased diet-related, non-communicable diseases, despite undernutrition persisting in many of these countries. This leads to

a phenomenon referred to as " the double burden of malnutrition", that is, the co-occurrence of both the burden of undernutrition and obesity in the same population. (1-6)

Obesity has reached substantial levels in LMICs. (7, 8) Consequently, it has become a major public health concern contributing substantially to the burden of disease in these countries. (9) With regards to different regions in the developing world, countries in Latin America and the Caribbean, especially Mexico, are highly affected. High levels of overweight and obesity have also been documented in the North African and Middle East regions. (3, 10) Rise in paediatric obesity is also becoming a major public health concern and is considered to drive the paediatric metabolic syndrome risk in LMICs. (11, 12) Paediatric obesity has adverse ramifications which may be short-term (for the overweight/obese child) or long-term (for the adult who was overweight/obese during childhood years). Common short-term consequences during childhood include heightened risk of psychosocial morbidity particularly in adolescents and in girls, asthma and morbidity from metabolic diseases. (12) Obesity developed during childhood or adolescence may persist to adulthood. (12, 13) Common longer-term consequences experienced during adulthood include heightened morbidity and premature mortality from cardiovascular diseases (CVD) and type II diabetes, and impaired social, educational and economic productivity. (12, 14, 15)

Despite the rising levels of obesity in the LMICs, undernutrition in children continues to be a great public health concern, particularly in sub-Saharan Africa. (16) Stunting is the most prevalent form of child undernutrition in these countries. Thirty two percent (178 million) of children aged less than five years are stunted. Africa is the most affected region with a prevalence of 40%. The prevalence of stunting in the sub-Saharan sub-region is about 43%. Underweight is the second most prevalent form of child undernutrition in LMICs. Twenty percent (112 million) of children under the age of five years in these countries are underweight. Africa and Asia are the most affected, and have similar prevalences of 22%. Within the African region, the prevalence of underweight is

higher in the sub-Saharan African region, with 25% of children under the age of five years being underweight. The prevalence of wasting is 10% (55 million) among children under five years in LMICs. The prevalence is highest in South-central Asia at 16%. (17)

Undernutrition has serious ramifications that are both short and long-term. In the short-term for the individual, it is a serious risk factor for ill health and mortality and loss in disability-adjusted life years (DALYs). (9, 18) In the long-term, adverse consequences of childhood undernutrition include impaired cognitive development, poorer educational achievement and human capital formation, (19, 20) and greater risk of obesity in adulthood. (21) Additionally, undernutrition may have adverse effects at the macro-level. It contributes substantially to the burden of disease in LMICs. It is associated with more than half of all child deaths, and is responsible for 15% of the total loss in DALYs in countries with high child mortality. High levels of undernutrition may ultimately affect the gross domestic product (GDP) through lowered economic productivity; about 2-3% of GDP in LMICs is lost to undernutrition. (19, 22) Further, since malnourished children are more likely to have poor educational outcomes leading over time to lower incomes, higher fertility, and suboptimal care for their children, this may contribute to the intergenerational transfer of poverty in LMICs. (19, 20)

The World Health Organization (WHO) recognised the public health implications of undernutrition and cosequently a goal to alleviate it was set among other millenium development goals (MDGs). MDG 1 of reducing hunger by half by 2015, is far from being met particularly in the sub-Saharan African region. Reasons for this include poverty, HIV/AIDS, conflicts and elusive gains in agricultural productivity. (22-24) HIV/AIDS plays a major role in the persistence of undernutrition particularly in sub-Saharan Africa. Its effects may be direct through its role on growth and nutritional status of infected children, (25-27) or indirect through its negative effects on care of young children, and on productivity and propagation of poverty, with consequent effect on

household food security. (28-31) HIV/AIDS persists as a global pandemic; 33.2 million people globally are living with HIV, of which 2.5 million are children aged less than 15 years. Close to 70% of people living with HIV, 22.5 million people, live in sub-Saharan Africa. (32)

Owing to its historical background, characterised by a nearly half a century of Apartheid that ended in 1994, South Africa is characterised by high levels of persisting undernutrition and particularly stunting among the Black population. (33-36) The prevalence of stunting among children aged less than five years was as high as 27% in 2003. (34) High levels of food insecurity have been reported in South Africa at the household level: 35% percent of households are food insecure despite South Africa being food-secure at the national level. (29) Further, South Africa experiences high levels of HIV/AIDS; about a fifth of people aged 15-49 years live with HIV. (32) Nationally, about a third of pregnant women visiting antenatal clinics are HIV infected. (37) The high prevalence of HIV/AIDS may aggravate the problem of both food insecurity and malnutrition.

On the other hand, rapid economic and social transition and urbanisation have been experienced in South Africa. Ecomomic growth has accelarated from an average of 1.0% in the last decade before the end of Apartheid to 5.1% in 2004-2007. (38) Rapid industrialisation following mineral discoveries in the late 19th Centuy set pace for rural-urban migration. Removal of mobility restrictions to urban areas for the Black majority post-Apartheid may have accelarated urbanisation; by 2001, urbanisation levels had reached 56%. (39) Consequently, a rapid nutrition transition has been experienced in the country. There is a marked shift towards an energy dense diet; studies in South Africa have reported decreased intake of the staple foods including maize meal and increased intake of energy-dense foods including added fats and oils and animal-derived foods occuring alongside urbanisation. (40-42) High levels of physical inactivity and sedentary lifestyles have also been associated with the nutrition transition in several studies in South Africa. (41, 43) As a

consequence, South Africa has a high prevalence of overweight and obesity among adults, particularly women (55%), (34, 42, 44) and a high disease burden of diet-related non-communicable diseases. (43)(45) Evidence of obesity among children and adolescents is emerging but limited. (33, 35, 46, 47)

1.2 Study justification

LMICs face a double-edged problem of malnutrition: the rising burden of overweight and obesity and the unfinished agenda of undernutrition. Furthermore, paediatric overweight and obesity are thought to drive paediatric metabolic syndrome risk as well as the risk of metabolic diseases in these countries. This double-faceted problem of malnutrition along with the risk for metabolic disease among children and adolescents, is not well understood as there are limited studies on paediatric overweight and obesity. (4, 6, 48) The World Health Organization (WHO) recommends more research on the frequency of risk factors to health and their levels in LMICs, (9) related to the metabolic syndrome. Given that the pace and nature of transitions vary across geo-cultural settings, local and context-specific data are increasingly stressed, particularly because such information is essential to local programming and policy. The range of literature on paediatric obesity and the risk for metabolic disease and co-existence with undernutrition is limited, particularly for rural areas in South Africa. (33, 46, 49) Of particular interest is evidence on the age and sex patterns of this co-existence and associated risk factors, as such evidence would inform specific policies and interventions to curb the problem.

HIV/AIDS impacts directly on the nutritional status of children. (25, 26)(27) The high prevalence of HIV in sub-Saharan Africa, and specifically in South Africa, among women of child-bearing age (37) indicates the need for community paediatric HIV screening for early and appropriate interventions. However, little paediatric HIV testing has been done on randomly selected children at the community level, hence little is known about patterns of malnutrition associated

with HIV status among randomly selected children. Most research on paediatric HIV focuses on hospitalised children or those enrolled in intervention programmes. Additionally, there is limited evidence on the feasibility and usefulness of paediatric HIV testing and disclosure with regards to caregiving and the health and wellbeing of children.

This study will add to the knowledge on undernutrition and its co-existence with overweight/obesity and metabolic disease risk in children and adolescents in a high HIV prevalent, rural setting in South Africa. The study will further contribute to knowledge with regards to the feasibility and usefulness of community paediatric HIV screening and patterns of malnutrition associated with HIV status in a randomly selected sample at the community level.

1.3 Aims and objectives of the study

1.3.1 Overall aims

This thesis seeks to better understand the profiles of malnutrition in a poor, high HIV prevalent, transitional society in a middle-income country - and in so doing, to inform policies and interventions to address the double burden of malnutrition.

1.3.2 Specific objectives

In the Agincourt sub-district, rural South Africa:

1. To describe age and sex patterns of undernutrition and obesity in children and adolescents aged 1-20 years.
2. To determine the prevalence and sex patterns of metabolic disease risk in adolescents aged 10-20 years.
3. To describe patterns of malnutrition by HIV status among children aged 1-4 years.
4. To determine the acceptability and usefulness of paediatric HIV testing to caregiving and nutritional outcomes.

5. To determine individual/child, maternal, household and community level factors associated with undernutrition in children aged 1-4 years, and overweight/obesity and risk for metabolic disease in adolescents aged 10-20 years.

1.4 Thesis themes

1.4.1 Overall theme

The overarching theme for this thesis is the double burden of malnutrition in transitional societies.

1.4.2 Specific themes

1. Patterns of malnutrition
2. Adolescent obesity and risk for metabolic disease
3. Child undernutrition in the context of HIV

The specific thesis themes and their relation to the 4 thesis papers are highlighted below (Table 1)

Table 1: Thesis themes and their relation to the 4 thesis papers

THEMES	**PAPERS***			
	I	**II**	**III**	**IV**
Patterns of malnutrition (objectives 1 & 2)	**X**			
Adolescent obesity and risk for metabolic disease (objective 5)	**X**			**X**
Child undernutrition in the context of HIV (objective 3, 4 & 5)		**X**	**X**	

* See list of papers on page iv

1.5 Structure of the thesis

This is a thesis with publications and is divided into two parts: the first part presents the integrating narrative, synthesising the results of all the thesis papers in a holistic manner, and the second part presents the four papers of this thesis (see list on page iv). The integrating narrative comprises six sections: 1. Introduction; 2. Literature review; 3 Methodology; 4. Results; 5. Discussion; 6. Implications, conclusions and recommendations.

Section 2 presents a review of literature on growth monitoring, importance of malnutrition with regards to millenium development goals, nutrition transition and the double burden of malnutrition in LMICs. It presents a review of the trends and drivers of the nutrition transition; the double burden of malnutrition and risk for metabolic disease, detailing the prevalence, causes and consequences of both undernutrition and overnutrition; and an account of the role of HIV in undernutrition. A review of South Africa as a transitional society is also presented, giving an overview of the historical background, economic transition, urbanisation, HIV situation, nutrition transition and nutritional status.

Section 3 presents the study methodology, giving an overview of the study setting and population and data and methods used. The subsection on study setting and population details the physical characteristics of the study area, basic services and socio-economic status. It also presents the health profile in the study area, with a focus on the burden of disease due to diet-related non-communicable diseases and HIV. The sub-section on data and methods presents details about the three data sources used in this thesis including study samples, sampling procedures and data collection procedures. It also presents details on the data quality control, data management and analysis and ethical considerations.

Section 4 Integrates the results according to the three thesis themes, and with reference to the four thesis papers. The first sub-section presents an overview of general characteristics of the study participants. Sub-section 2 presents patterns of malnutrition: undernutrition, overweight/obesity and risk for metabolic disease, with reference to Paper I. Sub-section three, with reference to Paper IV, presents results on adolescent obesity and the risk for metabolic disease examining the determinants at child, maternal, household and

community levels. Finally, sub-section four, with reference to Papers II & III, presents results on determinants of undernutrition among children aged 1-4 years, detailing the role of HIV status and other covariates at individual/child, maternal, household and community levels. The section further presents results on acceptability and perceived usefulness of paediatric HIV testing with disclosure and referral for standard health care.

Section 5 discusses the results thematically with reference to the three thesis themes. It relates the results to national and international findings. Study limitations are presented at the end of this section.

Section 6 presents a conclusion of the key findings and implications for further research, policy and practice with regards to the alleviation of malnutrition.

Part two includes the four thesis papers. Paper I presents the age and sex patterns of co-existing undernutrition and overweight/obesity in children and adolescents aged 1-20 years and the risk for metabolic disease among children and adolescents aged 10-20 years in rural South Africa. Paper 2 presents patterns of undernutrition by HIV status and covariates of malnutrition for children aged 1-4 years in rural South Africa. Paper 3 presents a narrative description of the perceived acceptability of paediatric HIV results and usefulness of knowing a child's HIV status with regards to caregiving. Paper 4 presents an account of the risk factors for adolescent overweight/obesity and risk for metabolic disease.

Appendices including data collection tools and ethical clearance certificates appear at the end of the document.

1.6 Conceptual framework

Figure 1 presents a conceptual framework adapted for this thesis illustrating the influence of nutrition transition on nutritional status at individual, household and community levels and the hierarchical organisation of the different societal levels that influence a child's nutritional status.

The framework is adapted from Popkin's (2003) model of nutrition transition, (2) and Griffiths (2004) framework of interpreting community, family and individual effects on child weight status. (50) The framework is also informed by the Food and Agriculture organization's (FAO)'s (2004) model on changes in food systems, (51) Davison's (2001) ecological model for childhood obesity, (52) and the UNICEF's (1990) causes of child malnutrition framework. (53) The framework recognises that nutrition transition and lifestyle changes, occurring in transitional societies, influence a child's nutritional status at different societal levels. The transition and lifestyle changes are driven by economic growth, urbanisation, globalisation inclusive of food markets, mass media growth, and technological changes. The framework further recognizes the hierarchical organisation of factors that influence a child's nutritional status: an individual child lives in a household/family which is located in a community. These factors are categorised into genetic, behavioural and environmental factors as illustrated in the model. Nutrition transition and lifestyle changes influence nutritional status directly at individual level, for example through behavioural changes including individual food preferences and intake, physical activity and sedentary behaviour. They also have an indirect influence through changes experienced at household and community levels. These may be behavioural, for example rural-urban migration, parental sedentary behaviour and change in food cultures; and environmental, including refrigeration at household level and availability of convenience food outlets and supermarkets in the community. (Figure1) In this thesis, children's nutritional status in a transitional society is described. Further, distal factors influencing a child's nutritional status are assessed including:

- Individual/child level: age, sex, birth weight, HIV status and pubertal development
- Household/family level: maternal factors including age, nationality, highest education level, marital/union status, co-residence with child and place of delivery (for index child); household head's factors including age, sex, highest education level and relationship to child; household food security and social economic status
- Community level: area of residence

The more proximal factors that may affect children's nutritional status including dietary patterns and food intake, health status (apart from HIV status), physical activity and sedentary behaviour, are not assessed. This is because data were not collected on these factors owing to financial limitations at the time. However plans are underway to explore these factors in future studies in the study area.

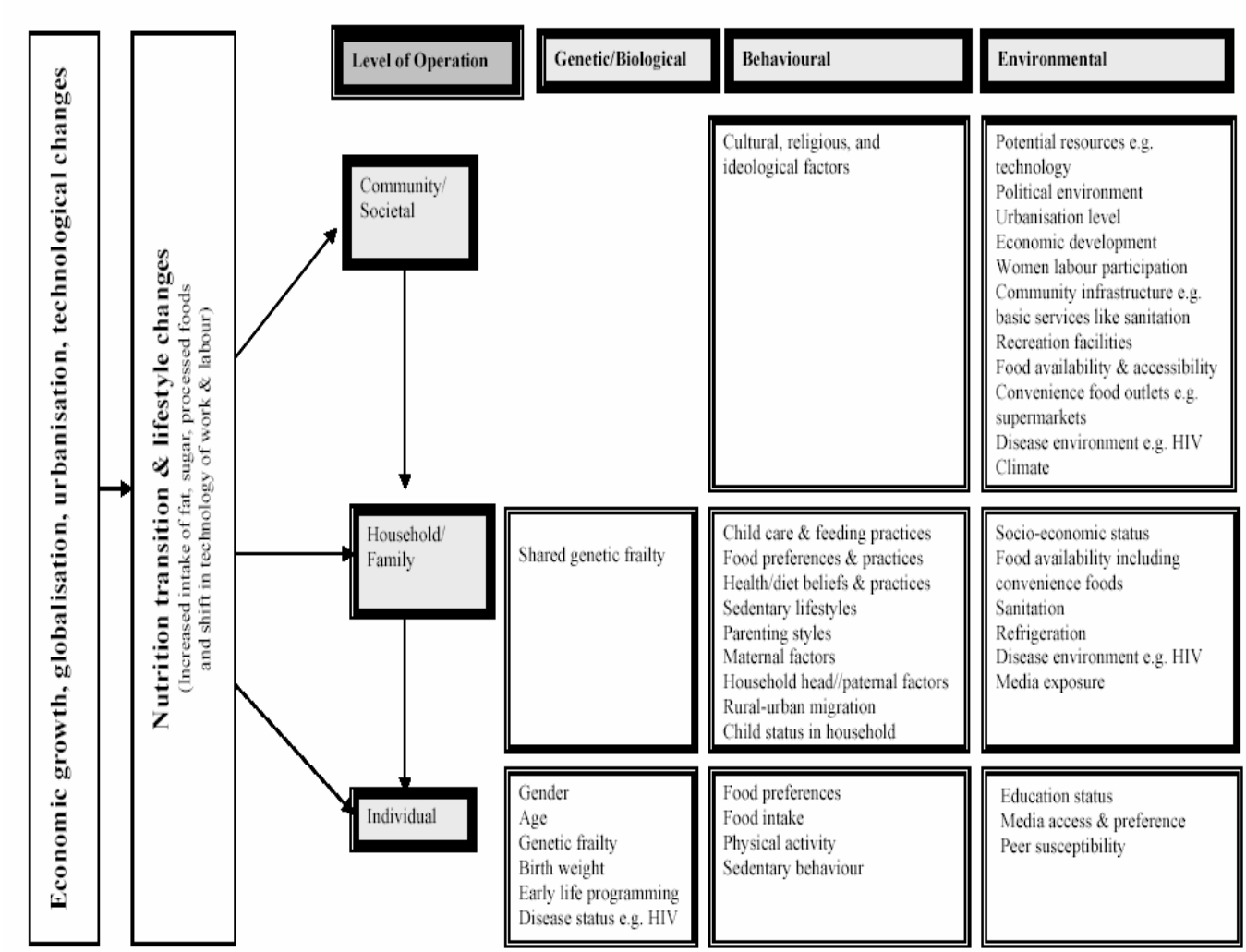

Figure 1: Conceptual framework on nutrition transition and hierarchical organisation of factors influencing a child's nutritional status

Source: adapted from Popkin (2003) (2) and Griffiths et al. (2004). (50) It is also informed by FAO (2004), (51) Davison and Birch (2001), (52) and UNICEF (1990). (53)

2.0 Literature Review

2.1 Growth monitoring

Growth in children and body dimensions at all ages reflect the health and welfare of populations. Therefore, anthropometry, a widely used inexpensive and non-invasive measure of detecting general nutritional status of an individual or a population group is often used to predict performance, health and survival. It is also commonly used to guide in public health decisions that affect the health and social welfare of individuals and populations. In the past, attention has been focused on infants and young children, particularly because of their vulnerability. However, advances in the recent past have demonstrated the importance of anthropometry in course of life at individual level as well as to demonstrate health status and socio-economic circumstances of populations. (54)

2.1.1 Growth references and standards

References and standards are used in comparing or making inferences based on the nutritional status of populations. A reference provides a common basis for comparing populations without making any value judgement/inference with regards to observed differences. A growth reference therefore indicates how other children (reference population) of the same age and sex (to that of the index population) are growing, or grew, at a specific place and time. A standard on the other hand represents the notion of a norm or target and therefore involves a value judgement. A growth standard defines how children are expected to grow. Therefore, if there is deviation from the pattern described by the standard, this indicates abnormal growth. (55)

Various growth references and standards have been developed for international use to determine the growth of children and other sub-populations. The most commonly used international growth

references and standards include the 1977 National Center for Health Statistics (NCHS) reference, the 2000 Centers for Disease Control and Prevention (CDC) reference (CDC, 2000) and the 2006 WHO growth standards.

2.1.1.1 NCHS reference

The reference developed by the United States (US) National Center for Health Statistics (1977 NCHS reference) are the most commonly used as reference for nutritional status in children. (56, 57) The reference was developed by combining two distinctive data sets representing different age groups, compiled in different decades. The reference for children aged 0-23 months was developed using data from children in the Ohio Research Insitute Longitudinal Study (Fels study) of 1929-1975. The reference population was fed primarily on infant formula and participation was restricted from within a specific genetic, geographic and socio-economic background. On the other hand, the reference for children aged 2-18 years was based on data from three cross-sectional US representative surveys conducted between 1960-1975. The NCHS reference, now referred to as NCHS/WHO was recommended for international use by the WHO in 1977, and is available for children aged up to 18 years. This followed recommendations of a working group convened in 1975 to advise the WHO on the use of anthropometric indicators of nutritional status for nutritional surveillance and in surveys. (58)

Though this is a reference and hence no inferences about growth should be made from it, it has often been used as a standard, particularly following studies a few decades ago indicating that the growth of young children is similar across different ethnic backgrounds. (59) Despite this justification, questions of validity and suitability of the use of this US-based reference have persisted in relation to its use internationally and have even been expressed in relation to its use for the US chilren. (54, 58, 60, 61)

Some of the limitations that have been cited with regards to this reference include:

- It was based on formula-fed children;
- It used two unrelated samples leading to large differences between recumbent length in the Fels data set and stature in the national data used for older children, hence a disjunction between the infants and older children curves between 24-36 months; and
- The weight-for-height charts ended at 10 or 11 years of age, hence the impossiblity of evaluating weight-for-height in adolescence.

Work supported by the WHO showed that the NCHS/WHO reference is adequately flawed so as to interfere with sound health and management of young children and infants. These flaws are from both biological and technical standpoints. Specifically, the reference may lead to early introduction of complementary foods in exclusively breastfed infants, with adverse consequences on their health and nutritional status. (61) These limitations led to the development of the the 2000 CDC reference (62) and the 2006 WHO standards. (63)

2.1.1.2 CDC reference

Following concerns about the suitability of the 1977 NCHS/WHO reference, together with the availability of more recent, comprehensive data and superior statistical smoothing procedures, revision of the 1977 NCHS/WHO growth charts was done. This led to the release of CDC growth charts in 2000 for the US. (62) The 2000 growth charts are based on data from five national health examination surveys collected between 1963-1994, as well as five supplementary data sets. Using statistical smoothing procedures, smoothed percentile curves were produced for infants and young children aged 0-36 months and older children from 2-20 years. As opposed to the 1977 NCHS/WHO reference, the 2000 CDC growth percentile curves for infants and older children are based primarily on national survey data. Hence there is a smooth transition from the charts for infants to those of older children. Additionally, the 2000 CDC references better represent the

racial/ethnic diversity and are based on combined breast and formula-fed infants in the US. New features (compared to the 1977 NCHS/WHO reference) include extension of all charts for children and adolescents up to 20 years. The revised reference may be a great improvement of the 1977 NCHS/WHO reference with regards to use in the US, especially given that it is based on more nationally representative data. (Kuczmarski, 2000 #2758}. However, questions arise as to its suitabilty for international use particularly for children in developing countries, and recommendations have been made for continued use of the 1977 NCHS/WHO reference until more appropriate alternative is found. (64)

2.1.1.3 WHO standards

Following questions on validity of the use of NCHS/WHO reference for children from other ethnic backgrounds, the WHO appointed a group of experts in the early 1990s to conduct a careful evaluation of the NCHS/WHO reference, which documented some limitations. (65) The outcome of the evaluation was the constitution of the Multicentre Growth Reference Study (MGRS), implemented between 1997 and 2003. The study was conducted internationally in diverse countries including Brazil, India, Ghana, Norway, Oman and the USA. The study involved healthy breastfed children that were raised in conducive environments that enhance full growth potential. (63)(66)

Following the MGRS, WHO growth standards were developed. The WHO standards recognise breastfeeding as the biological norm, hence a breastfed child is taken as the normative model with regards to growth and development. The WHO growth standards befit the label given the conditions under which they were developed, that promote full growth potential as described above, which were not present in the development of the NCHS/WHO reference. The WHO standards cover children aged from birth up to 60 completed months. (63)(66)

2.1.2 Measurements, indices, indicators & cut-offs

2.1.2.1 Measurements

Basic anthropometric measurements include age, length (in a recumbent position for children aged less than 24 months or = 85 cm), height (in standing position for those aged 24 months and above or >85cm) and weight. Other measurements may include waist circumference, hip circumference, skinfolds (biceps, triceps, sub-scapular and supra-iliac), head circumference and mid-upper-arm circumference. (54, 67)

2.1.2.2 Indices

Indices are combinations of measurements. They are important for the interpretation of measuments; for example a value of weight alone may not have any meaning unless it is combined with height or age. In children, the most commonly used anthropometric indices include weight-for-height, height-for-age and weight-for-age. Other indices commonly used for different age/physiological groups include waist-to-hip ratio, waist-to-height ratio and body mass index (BMI). Three reporting systems are used for indices: z-scores, percentiles, or percent of median, which can be used to compare children within a reference population. (54)

- Z-score (or standard deviation score) is the deviation of the value of an individual from the median value of the reference population, divided by the standard deviation of the reference population. A major advantage of using z-scores is ability to calculate summary statistics such as mean and standard deviation for a population. Commonly used z-score indices include: height-for-age z-scores (HAZ), weight-for-age z-scores (WAZ), weight-for-height z-scores (WHZ). Others include BMI-for-age z-scores (BAZ). Use of Z-scores is the preferred system.
- Percentile is the rank position of an individual on a given reference distribution. This is stated in terms of what percentage of the group the individual equals or exceeds. Percentiles are usually

used in clinical settings owing to their straightforward interpretation. A disadvantage is that they are inappropriate when used to calculate summary statistics such as a mean.

- Percent of median is the ratio of a measured value in the individual, e.g. weight to the median value, if the reference data for the same age or height is expressed as a percentage. A major disadvantage of using percent of median is the lack of exact correspondence with a fixed point of the distribution across age or height status. Additionally, typical cut-offs for percent of median are different for different anthropometric indices.

2.1.2.3 Indicators

An indicator is often constructed from indices, hence the term 'indicator' relates to the use or application of indices. An indicator may be used to indicate the state of health or nutritional status of a community. Commonly used indicators include:

Low weight-for-height: Low weight-for-height, referred to as wasting, mostly indicates current or acute and severe process of weight loss, which is often associated with acute starvation and/or severe disease. It may also be the result of a chronic unfavourable condition. So long as there is no severe food shortage, the prevalence of wasting is usually below 5%, even in low income countries (Table 2). (68)

Low height-for-age: Low height-for-age referred to as stunting indicates a process of failure to achieve linear growth potential due to suboptimal health and/or nutritional conditions. It reflects past or chronic undernutrition. In a population, a high level of stunting is associated with poverty and heightened risk of recurrent illnesses and early exposure to unfavourable circumstances including illness and/or improper feeding practices. A prevalence of stunting below 20% in a population is considered as low (Table 2). (68)

Low weight-for-age: Low weight-for-age, referred to as underweight, reflects both past (chronic) and/or current (acute) undernutrition, combining both stunting and wasting. However, it is unable to differentiate the two, hence difficult to interpret. A prevalence of underweight below 10% in a population is considered as low (Table 2). (68)

Table 2: Proposed epidemiological criteria for assessing the severity of undernutrtion in populations[a,b]

	Prevalence (%)			
Indicator	Low	Medium	High	Very High
Underweight	<10	10.0-19.9	20.0-29.9	= 30.0
Stunting	<20	20.0-29.9	30.0-39.9	= 40.0
Wasting	<5	5.0-9.9	10.0-14.9	= 15.0

[a] undernutrition defined as <-2 standard deviations of the median of the reference population

[b] Age < 60 months

Source: Gorstein (1994). (68)

2.1.2.4 Cut-offs

For population based nutritional assessment, results are commonly reported using cut-offs which enables the individual measurements to be converted to prevalence statistics. Cut-offs help identify children at higher risk of adverse outcomes.

For z-scores, cut-off values of <-2 and >+2 z-scores are commonly used, irrespective of the indicator used. The WHO Global Database on Child Growth and Malnutrition uses a z-score cut-off point of <-2 SD to classify low weight-for-height (wasting), low height-for-age (stunting) and low

weight-for-age (underweight) as moderate and severe undernutrition, and <-3 SD to define severe undernutrition. The cut-off point of >+2 SD classifies high weight-for-height as overweight in children. (69)

Other cut-offs include those for defining overweight/obesity using BMI and central obesity using waist circumference. The World Health Organisation classifies a BMI of:

- 18.5 to 24.9 kg/m^2 as normal
- 25·0-29.9 kg/m^2 as overweight
- 30·0 kg/m^2 or higher as obese

The criteria are recommended by the WHO for international use in defining overweight and obesity particularly in adults. (70) The International Obesity Task Force (IOTF) has recently come up with recommendations for determining overweight and obesity in children. This is based on data from six countries; US, UK, the Netherlands, Hong Kong, Singapore and Brazil. The IOTF recommends absolute age and sex specific cut-offs for BMI in children defined to pass through a BMI of 25 and 30 kg/m^2 at 18 years, for overweight and obesity respectively. (71)

There are no established criteria for determining central obesity in children. The existing cut-offs are mainly meant for adults. (70, 72) Recently, the International Diabetes Federation (IDF) released cut-offs for central obesity in defining metabolic syndrome. (72) These ethnic group specific cut-off points have been adopted by the WHO. (70) The cut-off points for waist circumference used for sub-Saharan Africans are those used for Europids:

- for males =94 cm
- for females =80 cm

Waist-to-hip ratio cut offs are also used to define central obesity. (70) These are:

- =0.95 for males
- =0.80 for females

Current studies have also recommended the use of waist-to-height ratio of 0.5 in estimating central obesity in both adults and children. (73)

2.2 Malnutrition and the millennium development goals

> "Sub-Saharan Africa is not on track to achieve a single MDG; it is off track on the hunger goal—and is the only region where child malnutrition is not declining." World Bank (2005). (74)

Undernutrition is recognised as one of the key development indicators, hence alleviating it is one of the millennium development goals. MDG 1 targets at halving between 1990 and 2015, the proportion of people who live in poverty and also the proportion of people who suffer from hunger. The hunger goal is measured by the proportion of children under age of five years who are underweight. The 2009 millennium development goals report indicates that progress towards meeting the MDGs is threatened by slow or even reversed economic growth among other factors. Progress in eradicating hunger has been made, however, this encouraging trend was reversed in 2008, majorly due to the worldwide escalation in food prices. The escalation in food prices is due to various factors including inappropriate agricultural policies, supply disruptions, rising demand due to changing diets, economic growth, demographic transitions and urbanisation, all of which have greatest impact on the poor. The prevalence of hunger rose in developing countries, from 16% in 2006 to 17% in 2008, despite some decrease in international food prices in the last half of 2008. (23)

The proportion of children younger than five years who were underweight in the developing world was reduced from 31% in 1990 to 26% in 2007. This progress is not adequate to achieve the MDG hunger goal. (23) In fact, a recent WHO study projected a substantially lower reduction in underweight prevalence (36%) between 1990 and 2015 than the MDG target. (75) The Latin America and Caribbean region is on track to meeting the goal, Asia is close to it, while Africa is off track. (23, 76) Eastern Asia, particularly China, was able to halve the proportion of underweight children between 1990 and 2007 while in contrast, and despite the improvements in Eastern Asia, slightly over 50% of children in Southern Asia are underweight. (23) The proportion of underweight children in sub-Saharan Africa has been marginally reduced from 31% in 1990 to 28% in 2007. Most of the countries making the least progress are in sub-Saharan Africa. The negative trends in sub-Saharan Africa may be associated with increased poverty, HIV/AIDS, conflict and elusive gains in agricultural productivity. (22, 24, 76)

Reducing malnutrition also has indirect implications on the achievement of the other MDGs. These include particularly the MDG 4, aimed at reducing mortality of children younger than five years by two-thirds from 1990 to 2015; MDG 2 aimed at achieving universal primary education; MDG 3 aimed at promoting gender equality, and empowering women; MDG 5 aimed at improving maternal health; and MDG 6 aimed at combatting HIV/AIDS, malaria and other diseases. (76)

2.3 Nutrition transition

2.3.1 Definition

Nutrition transition is the driving force behind the global obesity epidemic, becoming increasingly important in LMICs. (1-3, 51) Nutrition transition refers to changes in diet composition, commonly accompanied by changes in physical activity levels. Specifically, it refers to a shift from traditional diets mostly derived from plant-based food sources, to high energy dense foods and higher reliance

on processed foods. The plant-based foods are low in fat and are high in fibre and their production is labour intensive. The modern high energy dense foods are high in fat and sugars, are often processed and prepared outside of the home, requiring less labour.

Changes in dietary patterns can be summarised by two distinct phenomena occurring in transitional societies. These include diet convergence and diet adaptation. Diet convergence is due to reliance on a slim base of staple grains accompanied by enhanced consumption of animal source foods, salt, sugar and edible oil, and a decreased dietary fibre intake. It is driven by income and price of food, which are in turn influenced by supply and availability. As far as price is concerned, government subsidies maintain low prices for the three dominant global staples maize, rice and wheat. Higher fat intake which includes both animal fats and vegetable oil is currently possible at a lower gross national product (GNP) due to lowered prices. (2, 51, 77) On the other hand, dietary adaptation is described by heightened intake of brand-name processed and store-bought foods, an increase in the number of meals eaten outside the home and consumer behaviour. The main factor influencing dietary adaptation is lifestyle change driven by demands on time, availability of new foods and emergence of new food outlets, and a higher exposure to associated advertising. (51)

Nutrition transition occurs in three stages as described by Popkin (2003) (Figure 2). (2) These stages are driven by urbanisation, economic growth, technological changes for work, leisure and food processing and globalisation, including mass media growth. In stage 1 receding famine and historical periodic famines recede as incomes rise. The stage is characterised by diets primarily derived from plant-based food sources. The variety of food is low, while the foods are low in fat and high in fibre. Production of food at this stage is often home-based and is labour-intensive related to land preparation, planting, harvesting and processing. This is also characterised by nutritional deficiencies and high levels of undernutrition and there is slow mortality decline. Stage 2 involves degenerative disease and is characterised by dietary changes and activity patterns. There is

increased intake of animal products, higher fat intake (animal fat and vegetable oil) and increased intake of sugars. At this stage, there is higher reliance on processed food produced outside of the home, hence resulting in reduced physical activity. These dietary changes and decreased physical activity result in emerging obesity problems and increased diet-related non-communicable diseases. In stage 3 there is behavioural change where there is a reversal of the negative trends towards a process of a healthier form of aging. There is less reliance on processed foods with increased intake of fruits, vegetables, whole grain carbohydrates and high fibre. There is also increased non-obligatory physical activity to replace sedentary lifestyle. This regulation of intake and activity patterns results in reduced obesity levels and decreased diet-related non-communicable diseases. (2) The shift from stage 1 to stage 2 is often regarded as synonymous with the nutrition transition. Two primordial stages precede these stages: the stage of collecting food, characterised by hunter gatherer populations and the stage of famine, characterised by periods of acute food scarcity. (3)

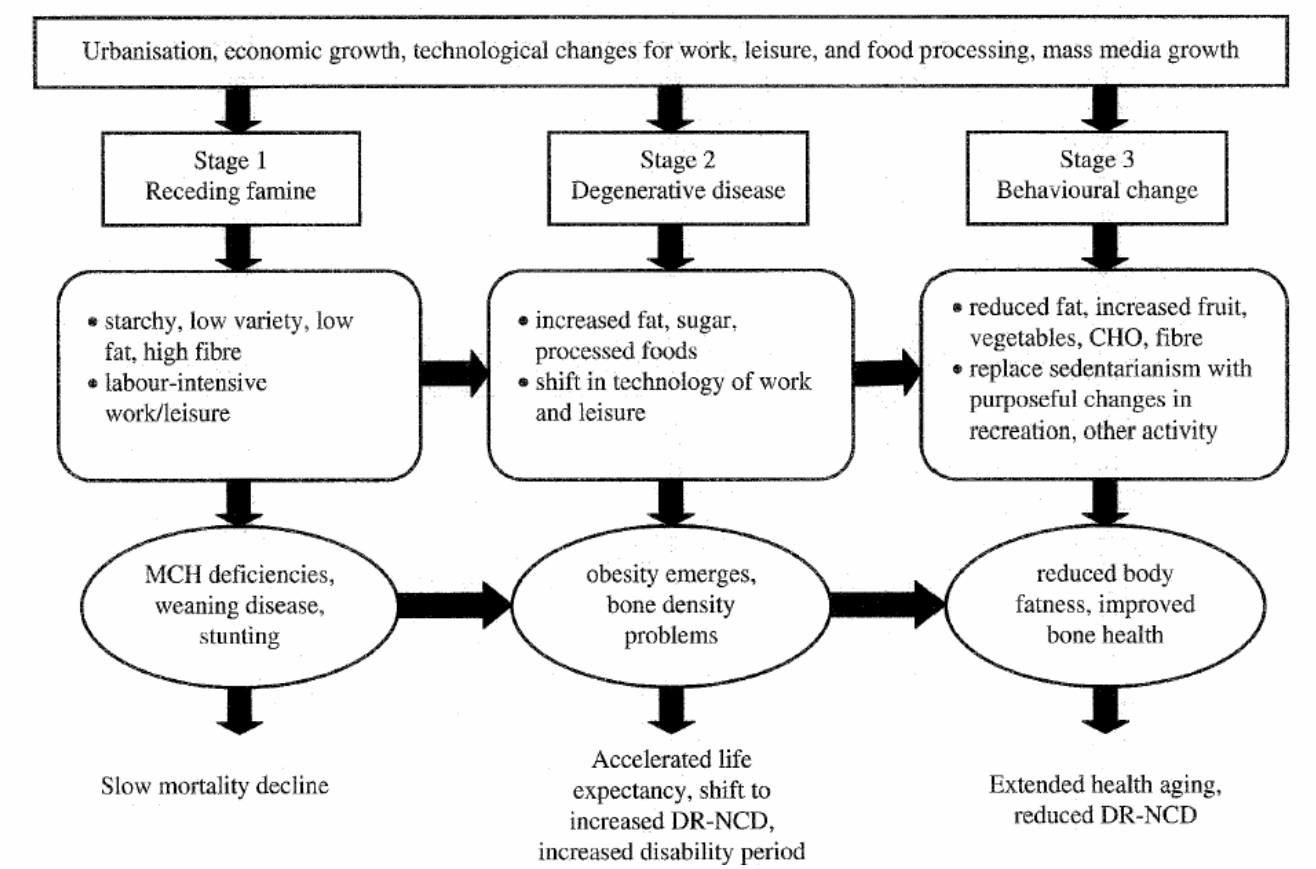

Figure 2: Stages of the nutrition transition

Source: Popkin 2003 (2)

2.3.2 Drivers of the nutrition transition

The nutrition transition is fuelled by several processes that lead to changes in food systems. These processes include economic transition, urbanisation, globalisation and social change. (51, 78)(79). As figure 3 shows, (51) increase in income, market liberalisation and foreign direct investment in markets as well as urbanisation, are the main economic drivers of food supply and diet change in developing countries. Additionally, concomitant social changes such as rural-urban migration, leisure and sedentary lifestyles and a higher number of women entering the workforce are also impacting on food supply and diet. Changes in food systems and diet lead to change in nutritional

status, with consequent higher levels of overweight and obesity and increasing disease burden due to nutrition-related non-communicable diseases.

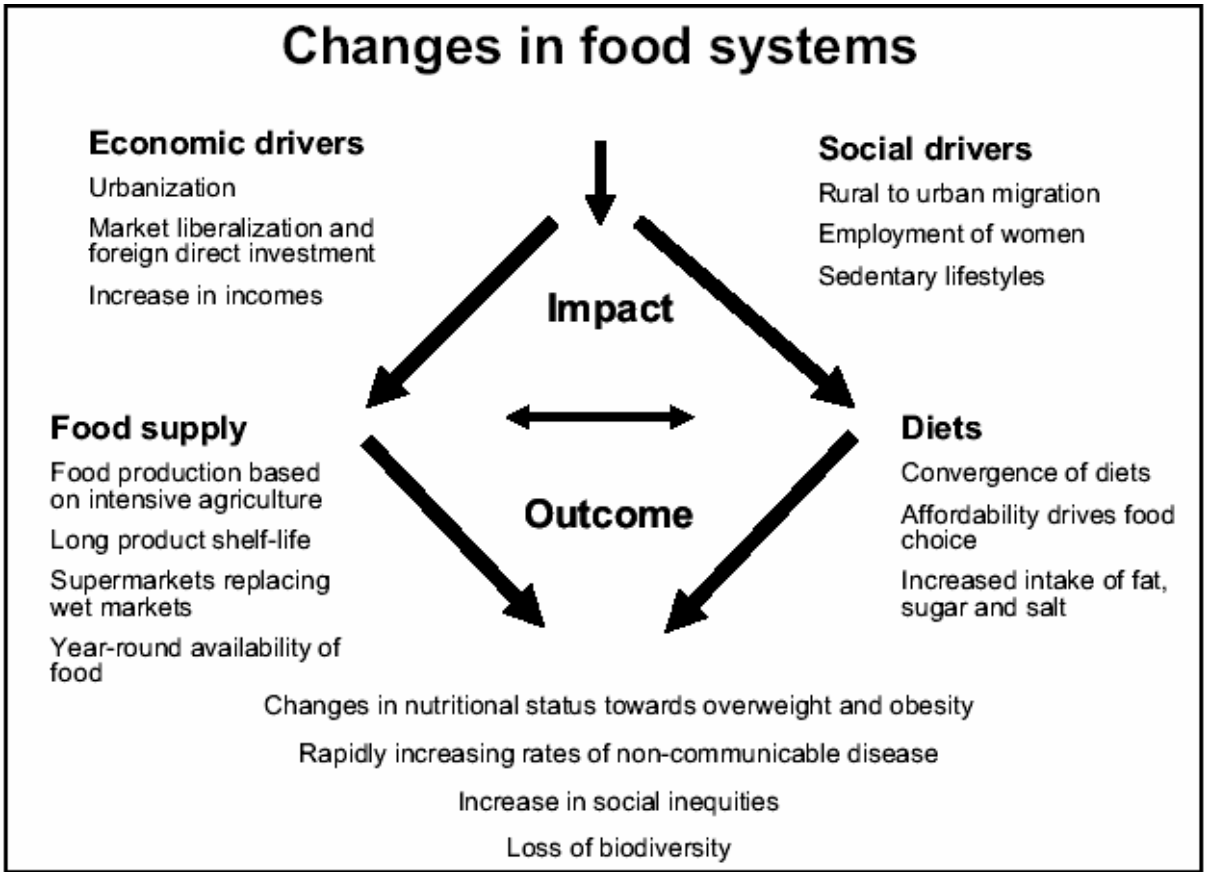

Figure 3: Changes in food systems leading to nutrition transition

Source: Food and Agriculture organization of the United Nations, 2004. (51)

Urbanisation and consequent lifestyle changes have a major role to play in influencing dietary change, as well as in the resultant changes in nutritional status and the changes in lifestyle associated with it. (78) Urbanisation is associated with increased rural-urban migration, improvement to infrastructure including electricity, roads, water and sanitation, improved access to communication including computer and internet, modern technologies including refrigeration and freezer technology. All these fuel change in dietary patterns. Urbanisation has both positive and negative impacts on the diet and diet-related consequences. On the positive side, it may enhance

food diversity and lead to better access to education and health care services. On the other hand, it may lead to negative impacts such as intake of energy dense foods and sedentary lifestyles. (51)

Rapid urbanisation has resulted in street foods and fast foods being increasingly important as a low-cost and quick meal option. These foods are often high energy dense, characterised by high fat and sugar content. Street foods refer to a wide range of ready-to-eat foods and beverages sold and sometimes prepared in public places, especially streets. Street foods range from traditional recipes such as rice or maize accompanied by vegetables and beans, to more modern recipes including potatoes, bread and various types of fried or grilled meats. (51, 80) Closely related to street vending of foods is street vending of carbonated soft drinks, high in sugar content, from multinational companies such as Coca-Cola. (51) Unlike street foods, fast food outlets specialise in a narrower range of foods, particularly chicken, chips, burgers, and pizza, usually prepared by frying. These foods are also usually accompanied by carbonated beverages. Fast food outlets are usually indoors. (51)(80) Globalisation of the fast food industry has been phenomenal in LMICs in the last few decades. The prevalence of multinational fast food restaurant chains such as MacDonald's and Kentucky Fried Chicken has increased dramatically. (81) There are also other more local food companies that may have a great impact including Galaxy biscuits for example in South Africa.

Additionally, there has been an increased growth of supermarkets in LMICs, characterised by the increased sale of processed and packaged foods, often exotic, sweetened, salted and with high fat content. (82, 83) The growth of supermarkets in LMICs is projected to increase further by 2015. (82) Significant explanatory factors of growth in the share of supermarket penetration in LMICs include GDP per capita, distribution of income, level of urbanisation, women labour force participation and openness to inward foreign investment. (82)

The increase of the number of women entering the workforce means less time to prepare meals at home, resulting in an increase in the intake of foods prepared outside the home. Rural-urban migration has also resulted in high demand for processed and packaged foods and also street foods and fast foods. This has led to increased market expansion of processed foods, street foods and fast food and convenience food outlets, and has great implications on dietary balance. (51, 80)

Apart from the driving force related to cost and convenience, secondary factors including advertising, marketing, as well as the appeal of new products and new retail outlets play a major role in dietary changes. (51, 84) Further, changing attitudes related to fast foods also have a major role in the changing dietary patterns. In some settings, fried foods are considered as a sign of wealth and modern living, while boiled foods are considered inferior and indicate outdated customs. (85)

2.3.3 Trends in the nutrition transition in the developing world

LMICs are now highly advanced in the nutrition transition. There are huge shifts in diet composition in these countries. (1, 2, 7) In case studies of six countries (China, Egypt, India, Mexico, the Phillipines, and South Africa) from 1970 to 2000, generally and with a few exceptions, declining intake of cereals, legumes, pulses and nuts and increasing intake of animal source foods, sugars and vegetable oil have been recorded. (1) For example, in China, a remarkable increase in the intake of fat particularly animal source fat, related to income increase, has been observed. More than 10% of Chinese adult total energy comes from animal fat. (79) The nutrition transition typically begins with urban populations and those of higher social economic status. (1) However, it is not limited to these populations. Increased intakes of animal source foods and edible oils have been documented in low-urbanicity urban areas and more urbanised rural areas. (77)

Latin American countries are particularly highly advanced in the nutrition transition. (3) Many countries in this region began nutrition transition earlier in the last century. However, there is great

heterogeneity. While countries such as Mexico and Brazil are highly advanced in the transition, others such as Haiti are still in the initial stages. In North Africa and the Middle East regions, advanced nutrition transition has also been documented in countries such as Egypt. (3, 86) Despite sub-Saharan Africa being the poorest region, its populations are shifting towards the patterns found in other regions. (3) Countries in Asia such as China have undergone great shifts in diet and physical activity patterns. (3, 87) South Korea has maintained its traditional diet to a greater extent where the percentage of energy from fat has remained low. (88)

2.3.4 Applicability of nutrition transition model in developing countries

Popkin's Model of nutrition transition indicates that nutrition transition occurs in 3 distinct stages where populations move from malnutrition (undernutrition) and deficiency related diseases to obesity, leading to nutritition related non-communicable diseases; then to behaviour change resulting in better health. (Figure 2). (2). This transition depicts more of what has happened in high income countries. The transition in low- to middle-income countries does not seem to follow the distinct stages observed in the high income countries. A nutrition paradox, whereby both undernutrition and deficiency-related diseases coexist with obesity is being observed in these countries. (4-6) (89) This may be as a result of inadequate access to proper nutrients that promote optimal growth in children in low-income settings, while access to and consumption of high-energy dense foods has been enhanced by the processes described above including globalisation, urbanisation, and social change. This co-existence has been documented at national level, community level, household level and also at individual level. (5, 6) (89) This phenomenon is commonly referred to as 'the double burden of malnutrition' described below.

2.4 The double burden of malnutrition

2.4.1 Definition

The double burden of malnutrition refers to the co-occurrence of both the burden of undernutrition and overnutrition in a population. This phenomenon, occurring in both middle and low-income countries such as South Africa and China, with very different cultures and dietary customs, is greatly due to the phenomenon of nutrition transition. (1, 90, 91) Evidence indicates that improvement in economic conditions may heighten prevalence of obesity and diet-related non-communicable diseases in countries with high levels of undernutrition. (1)

As described by Omran in 1971 in the theory of epidemiologic transition, (92) traditionally, undernutrition was associated with higher infectious diseases prevalence. As populations go through demographic and epidemiologic transition, prevalence of undernutrition and infectious diseases ceases to be important, while prevalence of overweight and obesity increases. This classical pattern of epidemiologic transition, constituting a shift from disease burden characterised by high rates of infectious diseases to increased degenerative diseases, was observed in most of Western Europe in the 19th Century. This shift was associated with economic development, change in ecobiologic factors and medical and public health improvements. The current trend in the burden of disease and malnutrition in LMICs is not classical; it depicts a modified pattern where infectious diseases coexist with chronic diseases and persist over prolonged periods of time. This pattern is referred to as the protracted-polarized model as described by Frenk. (93, 94) In this model, the more affluent of the society would have completed the epidemiologic transition, while on the other hand the poor experience high death rates due to pre-transitional pathologies, including infectious diseases and nutritional disorders, resulting in epidemiologic polarisation. Despite the poor suffering from high death rates due to infectious diseases and malnutrition, they are not shielded from chronic diseases

traditionally associated with affluence. Evidence of this model has been documented in several LMICs. (1, 90, 91)

Undernutrition and overweight/obesity both significantly contribute to the global burden of disease. They are both among the top 10 leading risk factors for the global disease burden. (9) The persistence of undernutrition is due to slow progress in improving water and sanitation and weak public health systems to combat the problem. On the other hand, the increase in obesity levels is associated with nutrition transition due to rapid urbanisation, changing dietary patterns and lifestyle, as described earlier.

2.4.2 Undernutrition

2.4.2.1 Prevalence of undernutrition

Undernutrition persists as a major public health problem in LMICs. Prevalence of undernutrition varies across different regions in the developing world with Africa and Asia being the most affected. (17, 76, 95) Additionally, within each country, prevalence varies across different socio-economic groups with the poorest sub-populations being the most affected. (96)

Stunting

Stunting remains the most prevalent form of child undernutrition in LMICs. (17, 76) Thirty two percent (178 million) of children aged less than five years in these countries are stunted. (17) There are wide disparities across the different regions in the developing world. Africa is the most affected region with a prevalence of 40%. Asia, given its high population, constitutes more than half of all stunted children in the developing world. Further disparities are seen across different countries in these sub-regions. For example India experiences a prevalence of 51%. Within Africa, the prevalence of stunting in sub-Saharan sub-region is about 43%. (17)

Underweight

Underweight is the second most prevalent form of child undernutrition in LMICs. (17, 76) Twenty percent (112 million) of children under the age of five years in these countries are underweight. Africa and Asia are about equally affected each with a prevalence of about 22%. Again, Asia constitutes more than half of all underweight children in the developing world. Within the African region, the prevalence of underweight is very high in sub-Saharan Africa, with 25% of children under the age of five years being underweight. (17)

Wasting

Wasting affects 10% (55 million) of children under five years in low-to-middle income countries (17). South-central Asia is the most affected with 16% of children affected. Severe wasting (weight-for-height z-scores of <-3), which is important as a criterion for therapeutic feeding interventions, affects 3.5% of children under the age of five years in developing countries. Africa is the most Affected region, with a prevalence of 4%. Again, Asia hosts the greatest proportion of severely wasted children; more than two-thirds. The prevalence of severe wasting in sub-Saharan Africa is about 4%. (17)

2.4.2.2 Causes of child undernutrition

The causes of child undernutrition have been described in various models (50) (53) (97) In UNICEF's 1990 framework of the causes of child malnutrition, (53) (Figure 4), undernutrition occurs as a result of a group of factors at individual/child, familial/household,and the wider societal/community level. Child level factors such as inadequate dietary intake are influenced by familial/household factors such as inadequate access to food and poor water and sanitation, which are in turn influenced by societal-level factors. In the UNICEF model, these causes are grouped into three main categories including immediate, underlying and basic causes. The immediate causes include inadequate dietary intake and health status. In the developing world, infectious diseases

including diarrhoeal and acute respiratory infections contribute to most nutrition-related health problems. The underlying causes include household food insecurity, insufficient maternal and childcare practices, health services and a healthy environment - particularly water and sanitation. The basic causes include economic, political and ideological structures and potential resources including people, environment and technology.

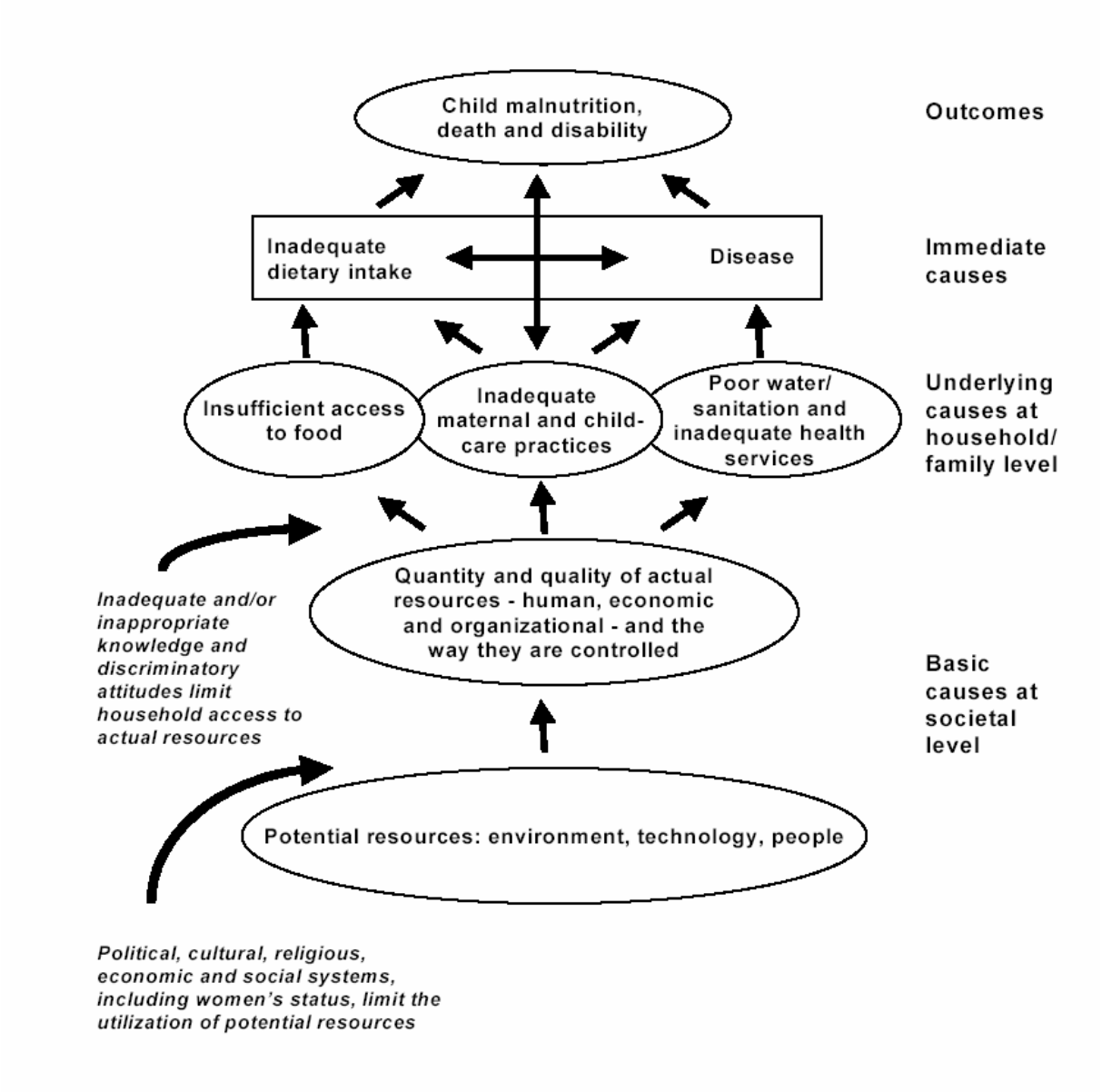

Figure 4: Causes of child undernutrition

Source: UNICEF (1990). (53)

Griffiths et al. (2004) have also developed a framework for interpreting community, family and individual effects on child nutritional status, (50) (see Figure 1), similar to the UNICEF's model. (53) This is adapted from a framework developed by Sastry for interpreting how clustering at family and community level affects child survival. (98) This framework recognizes different levels of societal hierarchy and their influence on a child's nutritional outcomes. It is built on the premise that an individual child lives in a household, which is located in a community, which in turn operates under government policies. The different levels influence a child's nutritional status through genetic, behavioural, and environmental factors. (98)

Different studies confirm the influence of child, household and community level factors on child's nutritional status. At the child level, several studies in LMICs have found an inverse relationship between age and undernutrition. (99) The relationship between nutritional outcomes and gender has been varied with some studies reporting male children as being more vulnerable to undernutrition (99, 100); some others, particularly in Asia, indicate higher vulnerability among girls (101); while still others imply the absence of gender effects on nutritional status. (102) Children who are born with low birth weight (<2500g) are more likely to exhibit undernutrition than children with normal birth weight (=2500g). (103) Child health status has also been associated with nutritional outcomes. For example, recent diarrhoea episodes have been associated with poorer nutritional outcomes. (50, 103) Being HIV infected has further been associated with poorer nutritional outcomes. (25, 26)

At maternal level, children of younger mothers, particularly of teenage mothers, are more likely to be malnourished. (104) Additionally, a child's nutritional status improves with the mother's level of education. (99, 105) The pathways that link maternal education to nutritional status include socio-economic status, health care knowledge and modern attitudes about health care. (106) Child care practices by the mother influence a child's nutritional status. Exclusive breastfeeding for at least six months is associated with better nutritional outcomes. (103) However, prolonged

breastfeeding has also been associated with poorer nutritional outcomes in some studies. (50, 107) Some studies have indicated that children who live with their mothers have a better nutritional status compared to children who do not live with their mothers. (108) Additionally, some studies have reported poorer nutritional status among children of working mothers, particularly that of younger children, (109, 110) and particularly if the mother works in the informal sector. (109) The poor nutritional outcomes for children of working mothers are especially related to suboptimal breastfeeding, especially among infants. (111) On the other hand, working in the formal sector and mother's income have been associated with better nutritional outcomes for the child. (103, 112) Maternal health seeking behaviour has also been documented as being positively associated with nutritional outcomes of their children. (113)

At the household level, children from food-insecure households exhibit poorer nutritional outcomes than children from food-secure households. (101) Education level of the household head or the father, which may relate to socio-economic status and food security has been positively associated with a child's nutritional status. (114) Additionally, household size (101) and number of children in the family (103, 115) are inversely associated with nutritional status. However, some studies have also found that having a large family guards against undernutrition. (103) Improved household water and sanitation are positively related to child's nutritional status. (113, 116) Further, household socio-economic status is inversely related to undernutrition. (99, 115)

At the community level, environmental factors such as proportion of households with improved water and sanitation, are positively associated with better nutritional outcomes, (115) although some studies have found no association. (99) Availability of health services such as health posts and non-governmental organisations (NGOs) in the community has also been positively associated with better nutritional outcomes in children. (104) Studies have also found that

children living in rural areas are more likely to be undernourished compared to children living in urban areas. (35, 99)

2.4.2.3 Consequences and importance of paediatric undernutrition

Morbidity, mortality and disease burden

> Undernutrtion "is implicated in more than half of all child deaths worldwide — a proportion unmatched by any infectious disease since the Black Death. Yet it is not an infectious disease. Its ravages extend to the millions of survivors who are left crippled, chronically vulnerable to illness —and intellectually disabled. It imperils women, families and, ultimately, the viability of whole societies". (97)

Undernutrition is a serious risk factor for ill health. (17, 18, 117) It is one of the top ten most important risks to health. (9) It leads to increased mortality and contributes substantially to the burden of disease in LMICs. It is associated with more than half of all child deaths. (18, 97) This is mainly due to its influence on morbidity from the major causes of child death including acute respiratory illnesses, diarrhoea, malaria and measles. (17, 117) Black et al. (2008) (17) reviewed data sets from eight low-income countries (Ghana, Guinea Bissau, Senegal, the Philippines, Nepal, Pakistan, India, and Bangladesh) to determine disease risks associated with childhood undenutrition. They found that undernutrition was associated with the risk of all-cause mortality as well as pneumonia, diarrhoea, malaria and measles. Undernutrition is also a major factor for loss in DALYs. Underweight accounts for the largest disease burden; 2.0 million (19%) deaths and 81 million (18%) loss in DALYS in children under five years. Stunting, severe wasting, and intrauterine growth restriction together account for 2.2 million (21%) deaths globally and 91 million (21%) of the total loss in DALYs in children under five years. The disease burden

attributed to undernutrition is highest in South-East Asia; India in particular. It is also high in Eastern, Middle and Western Africa. (17)

Cognitive development, human capital and poverty

Undernutrition is associated with impaired mental and cognitive development. (20, 97) This is partly because undernutrition dulls motivation and curiosity, hence reducing play and involvement in exploratory activities. (97) Survivors of undernutrition have poorer educational achievement, they become adults with decreased physical and intellectual ability and hence of lower productivity. Additionally, they face greater risk of obesity in adulthood with heightened risk of chronic diseases and disability. (21) All these lead to lowered human capital and hence poverty. (19, 22)

Undernutrition is directly and indirectly associated with poverty. It drags economic growth and propagates poverty through three routes (22):

- It directly lowers productivity due to poor physical activity;
- It results in direct losses due to poor mental and cognitive development, hence to lowered human capital; and
- It results in indirect losses due to heightened health care costs. Economic losses associated with malnutrition are important.

Productivity losses at individual level due to undernutrition are estimated at greater than 10% of lifetime earnings. At the national level, 2 to 3% of GDP is lost to undernutrition. (22)

2.4.2.4 HIV and undernutrition

HIV/AIDS persists as a global problem; 33.2 million people are living with HIV, of which 2.5 million are children aged less than 15 years. The majority of people living with HIV - close to

70% or 22.5 million people, live in sub-Saharan Africa. About half (15.4 million) of all people living with HIV are women of child-bearing age; while about 61% of adults living with HIV in sub-Saharan Africa are women. (32)

HIV/AIDS adversely impacts on the nutritional status of children. (118) It is associated with decreased food intake due to anorexia or co-morbid conditions and malabsorption and increased utilisation and excretion of nutrients, which may lead to nutritional deficiencies in infected children. (27) Studies in sub-Saharan Africa have attributed growth failure to HIV. (25, 26) Recurrent illness in HIV positive children due to lowered immunity may have a major role in their nutritional outcomes. Diarrhoea, which is a common opportunistic infection in HIV positive children, is particularly important in the growth retardation of infected children. (119)

HIV infection in the mother has implications on the nutritional status of the foetus which translates to nutritional status of the child later. Maternal HIV infection which leads to higher rates of maternal opportunistic infection has been associated with foetal growth retardation leading to smaller size and low birth weight. (120) HIV infected children born to HIV infected mothers have also been found to have a lower birth weight as compared to HIV un-infected children born to HIV positive mothers. (121) Additionally, HIV/AIDS has enormous impact on food security of affected households. It strips households of assets and undermines their ability to provide for basic needs. (28-31) HIV/AIDS results in loss of prime-age labour, leading to farming of less labour-intensive and less nutritious crops. (31) It weakens extended family networks, which are important for shielding against food insecurity, particularly in rural areas. (122)

On the other hand, undernutrition influences disease progression, increases morbidity and lowers survival of HIV infected persons. (26, 123) HIV positive children who are malnourished have higher rates of death compared to their non-malnourished counterparts. (26) For example, a study

conducted in Uganda found that death in HIV infected children younger than 25 months was nearly five times higher in children with lower weight-for-age-z-scores as compared to those with higher z-scores. (26) Height velocity in HIV infected children is particularly more important in disease progression. (124) Studies have associated height growth to survival, independent of viral load and CD4 T-cell count. (125)

2.4.3 Overweight and obesity

2.4.3.1 Prevalence of overweight/obesity

The problem of overweight/obesity has reached significant levels globally and is replacing the more traditional health problems such as infectious diseases and undernutrition as the most important risks to ill health. (8) James and colleagues (2004), (8) (quoting estimates from the International Obesity Task Force database) indicated that at least 1.1 billion people globally are overweight or obese. The prevalence of obesity in middle-aged adults ranges from 5% in some parts of Africa to almost 80% in Eastern Europe. (126)

The nutrition transition in the developing world has led to high levels of overweight and obesity. (3, 79, 126) With regards to different regions in the developing world, countries in Latin America and the Caribbean, especially Mexico, are highly affected. (3, 10) In North Africa and the Middle East region, high levels of overweight and obesity have also been documented. For example, Egypt suffers very high rates of overweight and obesity, and obesity co-morbidities such as hypertension and diabetes. Prevalence of overweight and obesity among women is as high as 70% while that of men is 48%. (3, 86)

Though sub-Saharan Africa is the poorest region, and obesity has not been a major problem, the populations are shifting towards the patterns found in other regions. (3) Even in the poorest of the

countries in this region such as Tanzania, notable prevalence of overweight/obesity and the rising importance of diet related non-communicable diseases has been experienced. (127) In countries in Asia such as China, overweight and obesity are lower than in many other regions but are emerging as major public health problems. (3, 87) Despite this, there is high prevalence of diet-related non-communicable diseases due to changes in diet, activity and body composition. (87) India has the highest absolute number of new cases of diabetes in the world, and together with China, they constitute the majority of diabetic cases in the world. (87, 128) In South Korea, though the prevalence of obesity is high, it is lower than expected for a country with its relatively high level of income. (88)

Childhood overweight/obesity is increasingly becoming a global public health concern. Using the CDC reference, (129) an estimated 22 million children aged less than five years worldwide are overweight/obese. A systematic review of surveys done between 1950-2007 in the developing countries indicated that childhood overweight/obesity is becoming increasingly prevalent in these countries. The review indicated that the highest prevalence of childhood overweight/obesity was found in Eastern Europe, and the Middle East, while the lowest was in India and Sri Lanka. (11)

Among preschoolers, de Onis et al. in 2000 (130) reviewed 160 nationally representative surveys from 94 countries collected between 1970 and 2000. They indicated that the prevalence of overweight (defined as weight-for-height >+2 SDs from the NCHS/WHO reference median) was 3.3% among those developing countries included. Latin America and the Caribbean had the highest prevalence (4.4%). With respect to UN sub-regions, North Africa had the highest prevalence (8.1%). Southern Africa ranked second (6.5%), driven by South Africa (6.7%). In some countries including Uzbekistan, Egypt, Peru, Argentina, Malawi, Nigeria, Qatar and Jamaica, the prevalence of overweight exceeded that of the US. (130) A similar review of 71 national nutrition surveys from 50 countries in the developing world between 1986 and 2000 found similar results. (131)

The prevalence of overweight/obesity is reported as higher in older children and adolescents as compared to preschoolers. As with younger children, in developing countries, there is variation across regions and across countries. Overweight and obesity in older children and adolescents is reportedly highest in childen and adolescents in the Middle East and in Central and Eastern Europe. (11) In Africa, a high prevalence of overweight and obesity has been reported in North Africa in countries such as Egypt, (132, 133) and in the Southern African region particularly in South Africa. (46, 133)

2.4.3.2 Causes of paediatric overweight/obesity

Obesity reflects an imbalance between energy intake and expenditure, with the excess energy being stored as fat. Developmental programming leading to the development of obesity and critical stages during which obesity develops, have been described. Additionally, factors associated with paediatric overweight/obesity have also been described.

Developmental factors

Dietz (1994) (134) has described 3 critical periods for the development of obesity and related complications. These include the early life period (prenatal and perinatal), the period of adiposity rebound during mid-childhood years; i.e. between the age of 5 and 7 years and adolescence.

Early life period

Prenatal and perinatal undernutrition or overnutrition influences adiposity later in life. Based on follow-up studies of infants, (135, 136) Dietz strongly hypothesised that low birth weight related to exposure to undernutrition during the first trimester confers a higher risk of later adiposity and hypertension or diabetes to the child. On the other hand, low birth weight due to third trimester maternal undernutrition confers a higher risk of later diabetes and hypertension, but not obesity. On

the other hand, exposure of infants to maternal overnutrition may confer a higher risk of obesity but a reduced risk of subsequent morbidity to infants. (134) In a later review, Martorell (2001) (137) also concluded that overnutrition, represented by gestational diabetes or high birth weight is associated with subsequent fatness. On the other hand, the association between poor nutrition sduring early life and later adiposity was inconclusive; with some studies indicating that children with a low birth weight were more likely to have higher adiposity than children with normal birth weight. Transition from nutritional scarcity to abundance or from rural to urban areas during early childhood and later life respectively, has been linked to the association between low birth weight and obesity. (137)

Developmental programming during the prenatal and perinatal period that may have implications for the development of obesity and obesity-related health risks later in life, has been described. (138-141) Early life insults, for example exposure to prenatal maternal smoking, gestational undernutrition or overnutrition, inadequate breastfeeding duration and inadequate infant sleep duration may result in a child's programming that may lead to energy imbalance. A famous hypothesis with regards to developmental programming is the "thrifty phenotype hypothesis" also known as the "Barker hypothesis", proposed by Hales and Barker in 1992. (142) It states that adverse influences during early life, especially during the intrauterine period, can lead to permanent changes in metabolism and physiology which may further result in heightened risk of disease in adulthood. In response to poor prenatal nutrition, the compromised foetus adopts survival strategies to maximize survival postnatally. Metabolic programming occurs in a way that enhances survival in conditions of poor postnal nutrition. If the foetus is born to conditions of poor nutrition, it adapts well to the environment. On the other hand, if the foetus is born to conditions of nutritional abundance, this conflicts with earlier programming leading to adverse consequences including obesity, Type 2 diabetes and other metabolic syndrome features. (142) (Figure 5).

Various mechanisms through which programming occurs have been suggested. These include disruptions in organ function which may result in alterations in the secretion and sensitivity of insulin; disruptions in appetite regulation due to dysfunction of the central nervous system and increase in the size and/or number of fat cells or changes in adipose tissue function. (138, 143, 144) In response to its environment, a foetus may make physiological adaptations in preparation for postnatal life. For example, early insults may programme appetite regulatory mechanisms and may result in long-term consequences with regards to intake of food and food preference in later life. Developmental programming also has implications for energy sensing and the regulation of energy expenditure. Therefore, in individuals who are developmentally programmed, excess energy is progressively stored rather than sensed and regulated, increasing the risk of obesity and obesity-related morbidity in the lifecourse. (138)

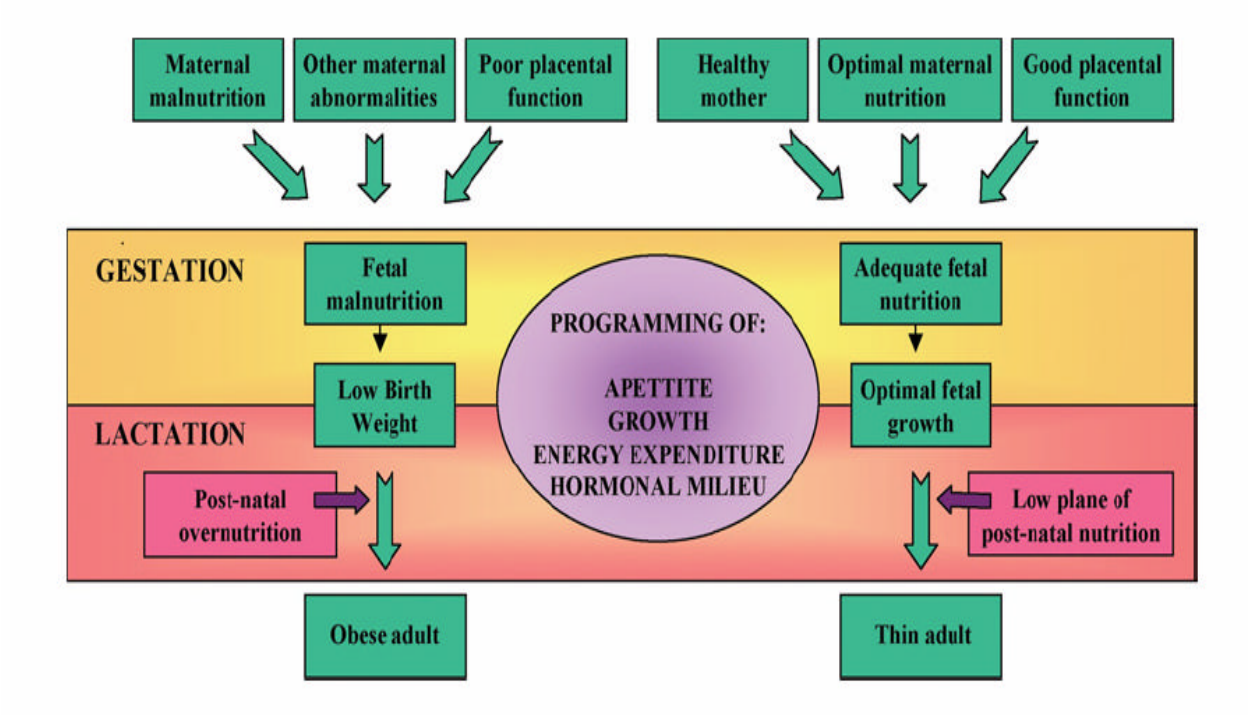

Figure 5: Developmental Programming of adult obesity

Source: Cripps (2005) (141)

Period of adiposity rebound

The time of adiposity rebound, between the age of 5 and 7 years represents another critical period for subsequent development of adiposity. (134, 145, 146) BMI increases in the first year of life but reduces in subsequent years. However, from about five years of age, BMI begins to increase again. This period, where BMI begins to increase again is referred to as the period of adiposity rebound. The time when this adiposity rebound occurs may have significant implications on adolescence and adult adiposity. The risk of increased BMI and adiposity in adolescence and adulthood is higher if adiposity rebound begins at an early age (before 5.5 years) than if it is average (6-6.5 years) or late (after 7 years). (146)

Adolescence

The final proposed critical stage for the development of obesity is during adolescence. (134, 135, 147, 148). Obesity that has its onset during adolescence will persist in approximately half of the adolescents into adulthood. (14) The risk of obesity development is seemingly higher and persists longer in females than in males (135). Adolescence also appears to be a critical period for the onset of obesity-related morbidity. (14, 147, 148)

Ecological factors

In a review of literature, Davison (2001) has described an ecological model of predictors of paediatric overweight/obesity, (52) (Figure 6) similar to UNICEF's model of causes of undernutrition, (53) using the Ecological Systems Theory (EST). (149) Under EST, human development is conceptualised to occur when interaction occurs within and among contexts. It emphasises the importance of consideration of the context(s) in which a person lives, in understanding the emergence of a characteristic. With regards to childhood development, its context(s) include the family/home and the school, which are found in larger social contexts that include the community and wider social and political environments. In addition to these contexts,

child characteristics including gender and age, interact with familial and societal characteristics to influence child development. (52, 149)

As shown in the model (Figure 6), behavioral patterns of a child include dietary intake, sedentary behaviours and physical activity, referred to as child risk factors in the model, may predict child's weight status. Child characteristics including gender, age and susceptibility to gaining weight moderate the impact of child risk factors on the development of overweight/obesity. Additionally, parenting styles including restrictions and encouragement and family characteristics, including the dietary patterns of the parents, child feeding practices and sibling and peer interactions, shape the development of child risk factors. Further, school environment characteristics, for example structured activity periods and school-feeding programmes, and community and the wider societal and environmental factors including availability of recreational space and facilities, influence the weight of the child. They influence a child's weight status through influencing the child risk factors and family factors.

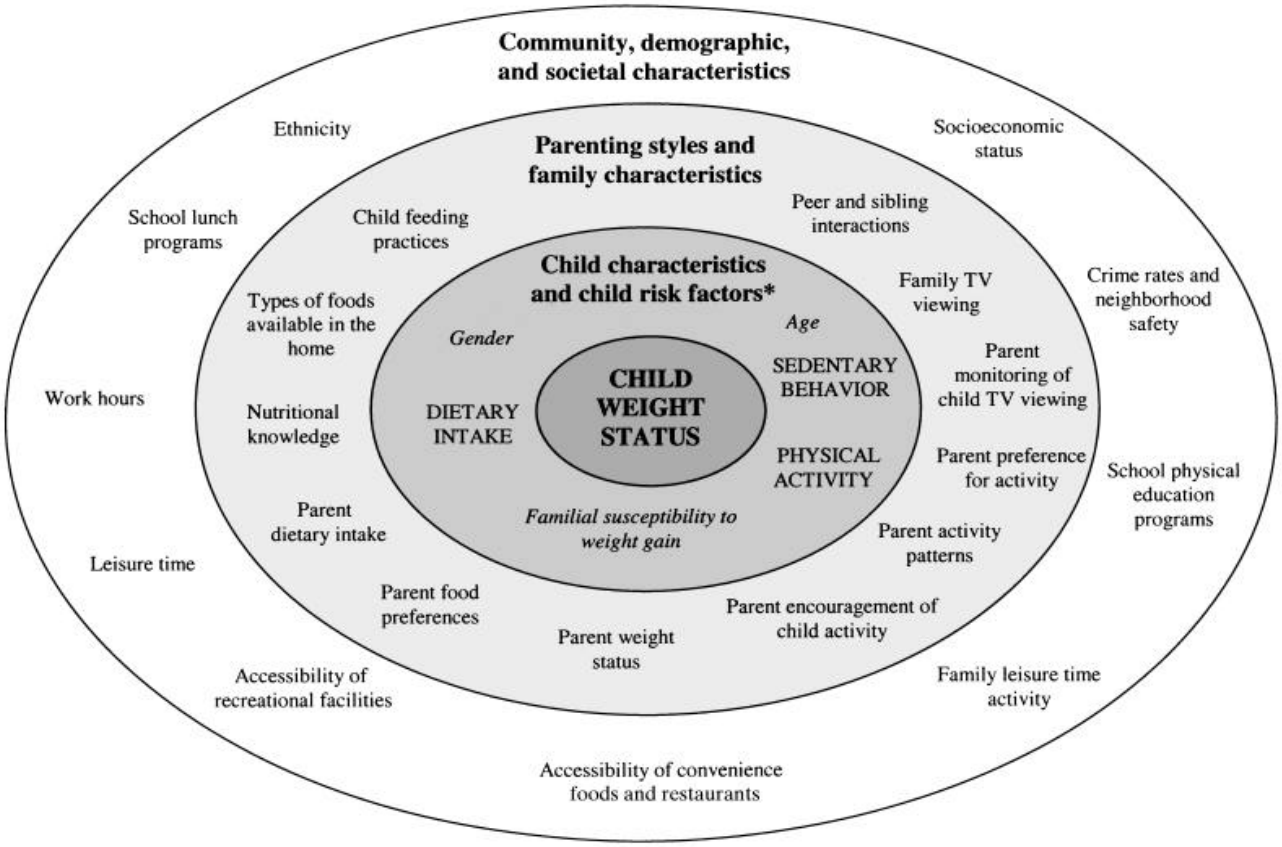

Figure 6: Ecological model of predictors of childhood overweight

Source: Davison 2001(52)

Dietary patterns

Excessive energy intake without reciprocal energy expenditure may lead to high fat storage in the body - hence the risk of overweight/obesity. Energy intake has been associated with increased BMI in children in various studies. (150)

The association between dietary patterns and child weight status may depend on child characteristics such as age, gender, rate of growth and familial susceptibility to weight gain. The energy needs of children differ for boys and girls as well as in relation to rate of growth.

Furthermore, the timing of growth spurts differs by sex, especially during adolescence. Overweight/obesity increases with age, particularly during adolescence, (47, 151) and may reflect the effect of sexual maturation or other factors such as increased sedentary behaviour with age. (152) Many studies document the higher prevalence of overweight/obesity among girls rather than boys, particularly during adolescence. (11, 47, 153) Studies have further documented a positive association between a child's overweight/obesity and parental BMI or fatness, (154, 155) which may reflect genetic susceptibility.

Family characteristics including parenting styles may also influence a child's dietary patterns. Studies have found similar dietary patterns between children and their parents. (52, 156) Despite these similarities in familial dietary patterns, a genetic explanation is not supported by research; individuals living in the same household tend to exhibit similar dietary patterns irrespective of genetic relationship. (156) The similarities in child-parent dietary patterns may therefore be reflective of environmental factors. The pathways through which parents may shape their children's dietary practices may include maternal nutritional knowledge, types of food availed by the parent to the child, parental child feeding practices and parental modeling of eating behaviour. (52, 157) Maternal nutritional knowledge and general health awareness affects diet composition availed to the child as well as portion sizes. Both are positively associated with the intake of fruits and vegetables by the child, and negatively associated with total energy and fat intake by the child. (157) Parents may act as role models for their children; children may prefer to eat the foods taken by their parents. (158) Again, parental feeding control may also affect a child's feeding patterns. (159) Parental overweight/obesity status is also associated with dietary patterns of the child. Studies have found that mothers who are overweight/obese are more likely to feed their children on snacks and high energy dense foods. A child's feeding patterns may also be shaped by peers and siblings. (52) Community, demographic, as well as wider societal and environmental factors including ethnicity, socioeconomic status, work status, and availability of convenience foods influence child-parent

feeding patterns. The participation of women in the workforce has reduced the time available for meal preparation, resulting in more consumption of convenience foods. Foods available in the community/environment including supermarkets are reflected in the types of foods provided to children by their parents. (52)

Physical activity patterns

Many studies have associated lower levels of physical activity with increased overweight/obesity in children. (52, 160) However, a few other studies have found no association. (52, 161) Physical activity patterns in children are influenced by a combination of child characteristics and family, peer and sibling physical activity patterns, which are in turn influenced by community and wider societal and environmental factors including school physical education programmes and availability of recreational facilities.

Child characteristics including age and gender influence a child's likelihood of participating in physical activities and sporting activities. Research indicates that boys are generally more physically active, participate more in sports and are more physically fit compared to girls. (162-164) There is also a documented decline in physical activity with age, from childhood to adolescence, in physical activity including participation in sports, particularly in girls. (165) This decline in physical activity with age may be explained by pubertal onset and the accompanying physical, social and emotional changes. (164) The gender difference in the decline may be due to the belief among girls that sports and physical activity are not feminine, which strengthens as they approach puberty. (165)

Family characteristics also shape children's physical activity patterns. Evidence indicates that the participation of parents in physical activity is positively associated with children's and adolescents' physical activity. Physical activity patterns among siblings and peers may also influence a child's

activity patterns especially during adolescence. (166) Family influence on child's physical activity is in turn influenced by community, wider societal and environmental factors including ethnicity, socio-economic factors, work status, accessibility to recreational facilities and security. School characteristics including physical activity programmes and recreational facilities in school influence a child's physical activity patterns. Ethnic differences may be explained by differential socio-economic status. Higher physical activity levels have been documented in higher socio-economic groups as compared to lower socio-economic groups, particularly in higher income countries. (52, 166) However, in lower income countries and particularly in areas where livelihood is highly dependent on subsistence farming, lower socio-economic groups may be involved in intensive labour on the farms hence enhancing their physcal activity levels. The association between socio-economic status and physical activity is varied in low- to middle-income countries. (167, 168) For example, a study in the phillipines associated higher socio-economic status with lower physical activity. (168) On the other hand, a study in South Africa associated higher socio-economic status with higher physical activity. (168) It is nevertheless worthwhile noting that in the same South African study, those in the lowest wealth quintile were also found to have higher physical activity, owing particularly to less ownership of TV.

Sedentary behaviour

Sedentary behaviours such as TV viewing, watching videos and playing computer games may put children at risk of overweight/obesity as evidenced by several studies. (160, 169) On the other hand, there is also some evidence suggesting that sedentary behaviour is not related to child's obesity. (170, 171). Sedentary behaviour may be associated with overweight/obesity due to its association with reduced physical activity. (163, 172) However, several studies have found that the association between sedentary behaviour and child weight status is independent of socio-economic and physical activity. (52) This then indicates that the influence of sedentary behaviours on child's weight status is not merely the result of physical activity displacement. The association of TV viewing to child's

weight status independent of physical activity status may be associated with other factors including for example food advertisement and the consequent request by children for the purchase of advertised foods. (84) Length of TV viewing by children has been associated with higher consumption of fast foods, and other high energy dense foods and lowered intake of fruits and vegetables. (173)

Child characteristics such as age and gender may influence the relationship between sedentary behaviour and risk of overweight/obesity. There is limited evidence on the differential effect of sedentary behaviour on the risk of overweight/obesity by age, albeit some evidence of decreasing risk by age during adolescence. (174) Some studies indicate that girls exhibit higher rates of sedentary behaviour than boys, particularly in the case of TV viewing. (52)

Parenting styles and family characteristics may influence sedentary behaviour in children. Parents shape sedentary behavior of their children by their own sedentary behaviour and by controlling their children's sedentary behaviour such as TV and video viewing. Community and wider societal level factors such as ethnicity, socio-economic status and availability of recreation facilities may also influence sedentary behaviour in children, particularly through their influence on parenting styles and family characteristics. Research has found lower parental monitoring and control of child's TV viewing among lower socio-economic groups. (52)

2.4.3.3 Consequences and importance of paediatric overweight/obesity

Paediatric obesity has adverse ramifications which may be short-term (for the overweight/obese child) and long-term (for the adult who was overweight/obese during childhood years). However, the consequences of paediatric obesity, being a problem of recent decades, have not been widely studied. Common short-term consequences of overweight/obesity during childhood and adolescence include heightened risk of psychosocial morbidity, particularly in adolescents and in girls who

undergo teasing and stigmatisation; ashma; orthopaedic difficulties; cardiovascular complications; type 2 diabetes; and to some extent type 1 diabetes. (12) Further, paediatric overweight/obesity is implicated in the development of paediatric metabolic syndrome. (11) Obesity developed during childhood or adolescence may persist to adulthood. (13, 14) Common longer term consequences, experienced during adulthood include heightened morbidity, heightened risk of premature death, and impaired social, educational and economic productivity particularly for women. (12, 14, 175) Moreover, obesity-related chronic diseases contribute substantially to the burden of disease in LMICs. (9)

2.4.4 Metabolic disease risk

Obesity and sedentary lifestyles are the root of the metabolic syndrome. Metabolic syndrome refers to a clustered presence of risk factors for cardiovascular diseases (CVD) and also for type 2 diabetes if it is not already present. These include obesity, insulin resistance, dyslipidaemia and hypertension. The clustered presence of these factors is associated with increased risk of future CVD and type 2 diabetes. (176) Several definitions for the MetS have been put across, the most accepted include the WHO definition (1999), (177) the European Group for the Study of Insulin Resistance (EGIR) definition (1999) (178) and the National Cholesterol Education Program—Third Adult Treatment Panel (NCEP-ATP III) definition (2001). (179) More recently, the International Diabetes Federation (IDF) came up with a new definition for MetS, using the 2001 NCEP-ATP III definition as the basis. (72) The main aim was to come up with a simple diagnostic tool for use in clinical practice as well as in research globally. While insulin resistance is not essential in the new definition as it is difficult to measure, central obesity, which is easier to measure is an integral component of the MetS. Thus, in the new definition, for one to be considered to have MetS, they must have central obesity plus any two of four additional components including raised triglyceride (TG) level, reduced high-density lipoprotein (HDL)-cholesterol, raised blood pressure and raised fasting plasma glucose. Central obesity is independently associated with all the metabolic syndrome

components (180), hence the basis for considering it integral in the new MetS definition. (72) This indicates that it has a pathophysiological role in the development of the MetS.

Childhood/adolescent obesity (including central adiposity) is the driving force behind paediatric metabolic syndrome risk that is becoming highly prevalent globally and within the LMICs. (11) Obesity signifies the most important risk factor for the development of insulin resistance in children and adolescents. (181) Insulin resistance is the most common metabolic alteration related to paediatric obesity and characterises an important link between obesity and other metabolic complications and CVD risk. (182) Studies have indicated that obesity in children is positively and significantly related with CVD risks. (12, 183, 184) Results of the Bogalusa Heart Study indicate that close to 60% of overweight children had at least one CVD risk factor while using overweight as a screening tool while it identified 50% of children with two or more risk factors. (183) Significant clustering of cardiovascular risk factors in paediatric obesity has also been observed in many studies. (12, 184) The extent of atherosclerosis in childhood has been associated with the number of risk factors present. (184) Expert opinions have consistently reached similar conclusions with regards to effects of childhood obesity on the cardiovascular system, pointing out similarities between children and adults in lifestyle factors and biological mechanisms through which obesity leads to CVD risk. (15, 185)

Childhood/adolescent obesity has been tracked into adulthood. (12, 13) For example, in the Bogalusa Heart Study, 77% of overweight children ((BMI =95th percentile), remained obese as adults (BMI =30 kg/m2). (186) Additionally, other risk factors for CVD associated with childhood/adolescent obesity have been tracked to adulthood. (12, 187) Further, childhood/adolescent obesity has been associated with increased cardiovascular and type 2 diabetes morbidity and mortality in adulthood. (12, 14)

2.5 South Africa: a society in transition

2.5.1 Historical background

South Africa has a long history of colonisation and racial segregation before the establishment of a democratic government in 1994. Apartheid laws were enacted in 1948, resulting in institutionalisation of racial discrimination and White supremacy. The Population Registration Act enacted in 1950 required racial classification of South Africans into racial groups including White, Black (African), Coloured (including people of mixed decent) and Asian/Indian. In addition, the Group Areas Act of 1950 resulted in the allocation of separate areas for different races. A basis for ethnic government in Black reserves known as “homelands” or “bantustans” was also established in the 1950s through the Bantu Authorities Act. This was meant to denationalise Black South Africans, hence denying them of their citizenship. Their political rights were therefore restricted to the designated homeland. Ten tribally based homelands were created, four of which became nominal independent states. The homelands later became the site for forced resettlements. Pass laws were enacted in 1952 requiring Blacks to carry passbooks so that their movement within the country could be regulated. Additionally, a Separate Amenities Act was established, separating the use of public amenities for Whites and non-Whites. (188, 189).

The Apartheid era was characterised by various restrictions including social restrictions such as the prohibition of marriage between non-Whites and Whites and employment discrimination, land access restrictions, forced resettlement and the restriction of mobility of Black Africans. There was also discriminatory development and provision of public services such as education, medical care, with the Blacks getting the most inferior services. Conditions at Black hospitals were poor and these hospitals were often overcrowded. Gender discrimination was also apparent. Women had very few or no legal rights at all; no right to education and no right to own property.

Mobility restrictions ensured that Black South Africans were cut-off from urban areas; only those who were required for the country's economy were allowed in urban areas, and they had to produce passes to get access to the urban areas. Men often found jobs in urban centers while women often stayed in rural areas. This resulted in family seperation as these men were not allowed to migrate with their wives and children to the urban areas. (188-191)

During the many decades of the colonial and Apartheid regimes, the Black majority population was expected to provide labour to growing mining and industry, and to large-scale agriculture. This deprived the Black majority South Africans of opportunities: access to land for cultivation, free participation in food markets, and economic opportunities. Poor living conditions for the Black majority of South Africans due to the racial segregation and deprivation resulted in adverse health outcomes, including high rates of sexually-transmitted diseases, respiratory illnesses, child malnutrition and other preventable diseases. (192-194)

2.5.2 Economic transition

Economic growth in South Africa has pivoted around political change. There was a long-term economic decline during the Apartheid regime, worst of all during the decade prior to 1994. This was followed by a reversal after transition to democracy in 1994, and a rapid growth to date. (38, 90). The decline in the economy prior to 1994 resulted from political instability, widespread international sanctions (trade and financial) imposed upon the Apartheid governmment as well as macro-economic policies intended to revive the economy that on the contrary led to increased inflation, uncertainty and declining investment. Economic opportunities were limited for most South Africans due to racial exclusion, limited skills and education levels, and limitations to market entry due to legal restictions. These factors further contributed to low rates of economic growth. (38)

The reversal in economic growth after 1994 resulted from a transition to a democracy along with the resulting establishment of political certainty, followed by confidence-building economic declarations and reforms reinforced in the early years of the post-Apartheid era. (38, 90) Economic decline rapidly changed to growth and has ever since accellerated steadily, from an average of 1.0% in the last decade prior to 1994 to 5.1% between 2004-2007. (38) A macro-economic and fiscal programme "Growth, Employment and Redistribution (GEAR) was published in 1996. The programme aimed at growth through the redistribution of wealth, fiscal restraint, privatisation and deregulation, and adopted the neo-liberal political approach. It was envisioned that the new policies would also enhance growth through attracting foreign direct investment which had collapsed during the Apartheid regime. (38, 90, 195)

Despite the expectations of the policy reforms and the observed economic growth post-Apartheid, unemployment, poverty and economic inequality are some of the fundamental socio-ecnomic issues facing South Africans in the post-Apartheid period. (38, 90, 195, 196) Sharp decline in employment, particularly in the manufacturing and textile industries, has resulted particularly from rapid dismantling of tariffs. The loss in employment has particularly affected the artisan and the unskilled workers, especially due to labour-displacing technical change. (195) Unemployment levels have grown from 33% in 1996 to 41% in 2001. Among the majority Black population, the levels have grown from 42.5% to over 50%. (90)

Though cautious of some differentials in data used (196), overwhelming evidence suggests that income poverty levels have increased in South Africa post-Apartheid in the late 1990s, despite the observed economic growth. (90, 195, 196) This poverty is racially and spatially defined; for example, between 1995 and 2005, absolute and relative poverty levels increased among Black-headed households while they remained stagnant or declined in non-Black households. With regards to the urban versus rural populations, poverty levels are higher in the rural areas. The

povery levels increased from 13-16% in urban areas and from 45-46% in rural areas for the same period. (196)

Inequality in income distribution in South Africa remains high, with a Gini coefficient that is still one of the highest post-Apartheid. (195, 196) However, it declined during the 1990's from 0.68 in 1975 to 0.67 in 1991, then to 0.57 in 2000.(195) This inequality is deeply rooted within the political background, with political exclusion that took a colonial and racial form. (195)

2.5.3 Urbanisation

The political background of South Africa has a significant role in its urbanisation patterns. (197) The broad pattern of Black urbanisation was laid out during the Apartheid era. Rapid industrialisation following mineral discoveries in the late 19th century led to an increased need for labour in urban areas. Since Blacks were expected to provide this labour force, this resulted in rural-urban migration of particularly men. However, the mobility restrictions during the era on the other hand restricted free rural-urban migration, and men often had to leave their families behind, as indicated earlier. South Africa has undergone rapid urbanisation since the end of the Apartheid period. By 2001, urbanisation levels had reached 56%. (39) The rapid urbanisation may in part be due to removal of the Apartheid restrictions that ensured limited entry of the Black majority population into large cities, following independence in 1994. Given the historical foundation of migration patterns amongst the Black population, temporary circular rural-urban migration and high level of social links between urban and rural households has been observed. (198)

The end of the long Apartheid era in South Africa was marked by a need to improve the living standards of the previously disadvantaged majority of South Africans, who mostly resided in rural areas. During the Apartheid era, rural areas were characterised by high poverty levels, limited employment and economic opportunities, poor infrastructure and limited services. Marginalised

communities were economically dependent on urban areas. Several rural development intitiatives have been taken on in South Africa post-Apartheid, including policies, strategies and programmes. It has been envisaged that the development of rural areas would enhance lives and ecomomic wellbeing of those living there and hence, among other anticipated results, curb rural-urban migration. Initial intiatives include the Reconstrution and Development Programme (RDP) of 1994, the Rural Development Strategy of 1995 and the Rural Development Framework of 1997. Poor implementation of these intial initiatives led to the conception of the Integrated Sustainable Rural Development Strategy (ISRDS). This strategy was created to address the fragmented, uncoordinated and unsustainable endeavors of the RDP. Key elements of the ISRDS include integration, rural development, sustainability, the growth dynamics in rural areas and rural safety nets, as an integral part of the ISRDS. For implementation purposes, the ISRDS was turned into a programme in 2001; the Integrated Sustainable Rural Development Programme (ISRDP), a 10 year programme expected to run from 2001 to 2010. The programme aims at transforming rural South Africa into an economically and socially stable sector. It was expected that by 2010, rural areas would have attained the internal capacity to ensure integrated and sustainable development. Initial development programmes include basic services such as access to roads, water, sanitation, and electricity. (199) It is not yet clear whether the internal capacity has been achieved as the programme is still running.

2.5.4 The HIV situation in South Africa

South Africa, in common with the neighbouring Southern African countries, is experiencing one of the most severe HIV epidemics in the world; about one in five people aged 15-49 years live with HIV. (32) Nationally, about a third of pregnant women visiting antenatal clinics are HIV-infected. (37) The prevalence of HIV among children aged 2-4 years is estimated at 5% (200). Close to half (47%) of overall mortality nationwide is estimated to be due to HIV AIDS. Additionally, approximately 50% of maternal orphans aged less than 18 years are orphaned due

to AIDS. Moreover, HIV-related mortality of children aged less than 15 years is estimated at 44%. (201)

HIV-related services such as HIV counselling and testing, prevention of mother to child transmission of HIV (PMTCT) programmes and anti-retroviral therapy (ART) have been scaled up in South Africa in the last few years. However, availability of, access to and utilisation of these services remain a challenge. (201-203) Utilisation of HIV related services is significantly undermined by stigma and discrimination, which remain unacceptably high in South Africa. (202, 204)

With regards to HIV testing, according to the South African Demographic and Health Survey of 2003, only 30% of women of child bearing age (15-49 years) reported having been tested for HIV in the last 12 months. One-third of these had not received their test results; making the proportion of those who knew their status only about 20%. An even smaller proportion of men in the same age group had been tested, but a higher proportion had received their test results, making the proportion of those who knew their status about equal to that of women (20%). (34)

Recognising the importance of PMTCT programs in preventing HIV infection in children and enhancing the health and wellbeing of mother and child, the South African government made a decision at the end of 2000 to implement PMTCT programmes nationally. Following this decision, two pilot PMTCT sites were initiated per province, 18 in total. (205) These have been scaled up nationally in the recent years, since 2002. The PMTCT programmes embody a set of activities forming a continuum from prevention of HIV in women, to care and support of HIV positive women and their children. The PMTCT services include VCT for pregnant women, short course Nevirapine to HIV positive pregnant women, appropriate counseling and support for safe infant feeding practices, and follow-up care to mother-child pairs after delivery. However,

these services only reach a minority of those at risk. This is largely due to difficulties in integrating the PMTCT programmes within maternal and child health services. There are however some milestones; for example, the proportion of pregnant women attending antenatal clinics who are receiving HIV counselling and testing has increased dramatically over time to close to 70% in 2006/7. (206) In 2003, 56% of women reported that they had been tested for HIV during antenatal visits. (34) The proportion of HIV positive pregant women who receive nevirapine is 61%. (206)

Access to ART remains a challenge for those who need it. Only 225 000 of the 5.4 million living with HIV in 2006 were estimated to be on ART, less than a third of the 711 000 infected people estimated to need it. (201)

2.5.5 Nutrition transition and the double burden of malnutrition

2.5.5.1 Nutrition transition and lifestyle changes

The rapid economic growth and urbanisation that have been experienced since the cessation of the Apartheid era and commencement of neo-liberal macro-economic policies have resulted in a rapid nutrition transition in the country. There is marked shift towards a high energy dense diet; studies in South Africa have reported decreased intake of the staple food including maize meal and increased intakes of energy-dense foods including added fats and oils and animal-derived foods with urbanisation. (40-42) The White, Coloured and Asian populations are already following a westernised diet. The Black population, particularly in urban areas is rapidly shifting from a traditional diet high in fibre and unrefined carbohydrate, to a more typically western diet high in added sugar, high fat content, lower in unrefined carbohydrate, higher intake of animal protein sources and increased saturated fat. (40)

A marked increase of multinational fast food chains such as Nandos, Steers, McDonalds and Kentucky Fried Chicken, soft drink companies such as Coca Cola and supermarket chains such as Shoprite and Pick 'n' Pay has occurred, particularly in the post-Apartheid era. This has contributed to change of diet from traditional to energy-dense diets. (85)

High levels of physical inactivity and sedentary lifestyles have been associated with the nutrition transition in several studies in South Africa. (41, 43) Recent national electrification and consequent increase in television ownership may have a major role in physical inactivity levels and sedentary lifestyles, particularly among children and adolescents. Among children and adolescents, physical inactivity has been reported as higher among girls than boys, particularly in adolescents. (151, 207)

2.5.5.2 Undernutrition

Owing to its historical background, South Africa is characterised by high levels of undernutrition. (33-36) (Table 3). Given the historically high levels of malnutrition, the post-Apartheid government in 1994 recognised it as one of the key prority areas to be addressed. Consequently, an integrated nutrition strategy was formulated and adopted by the Department of Health. The strategy was later developed into the Integrated Nutrition Programme, (208) adopting UNICEF's conceptual framework of malnutrition. (53) Despite political changes, rapid economic transition, and efforts to alleviate malnutrition in South Africa, these trends have persisted.

As shown on Table 3 below, stunting is by far the most prevalent undernutrition problem in South Africa at national level and both in urban and rural areas. Without disregard to the difference in the age groups studied in various national studies, which may account for some of the diffences observed, undernutrition does not seem to have declined during the post-apertheid

period. For example, in 1994, stunting was 23% for children aged 6-71 months. (36) The prevalence of stunting remained high at 22% in 1999 and 18% in 2005 for children aged 1-9 years. (33, 35) For younger children aged 0-5 years, prevalence of stunting was highly marked at 27% in 2003. (34) The prevalence of underweight seems to stabilize between 9-12%, while that of wasting seems to stabilize between 3-5% accross the different studies. (33, 35, 36)

Rural areas are the most highly affected compared to urban areas, with regards to magnitude. However, while in rural areas the prevalence seems stable particularly for stunting and underweight in younger children under six years of age, undernutrition seems to be worsening in the urban areas. (33, 36) Taking into account the slight age difference, for children aged less than 5 years, using the 1994 study as the baseline, the prevalence of stunting in rural areas is still marked at 28%, underweight seems stable at 11% while wasting seems to have increased to about 5% in 2003. The prevalence of stunting in urban areas has drastically increased from 16% in 1994 to 27% in 2003, almost equalling the prevalence in rural areas for the same age group. For the wider age group of 1-9 years, stunting has decreased in rural areas between 1999 and 2005, from 27% to 20% respectively. Likewise, there is some decline in prevalence of underweight and of wasting. On the other hand, the prevalence of stunting has hardly declined in urban areas; prevalence of underweight has increased slightly while prevalence of wasting has increased more than two-fold. (33, 35) Prevalence of undernutrition has been documented as higher in boys as compared to girls, particularly among adolescents. (46, 153)

The persistence of marked levels of undernutrition may be due to high levels of food insecurity which have been reported in South Africa at the household level; 35% of households are said to be food insecure. Paradoxically, despite the high reported levels of food insecurity at the household level, South Africa is said to be food-secure at the national level. (29) Further, the high prevalence of HIV/AIDS in South Africa may have aggravated the problem of both food

insecurity and undernutrition. HIV infection in children has been linked to growth failure in some studies in South Africa, (209) and higher hospital admission of malnourished children. (210)

The high levels of undernutrition in South Africa are comparable to rates observed in low-income countries. For example, despite South Africa being a middle-income country, its stunting levels are similar to those of low-income countries such as Senegal and Togo. (76, 211)

2.5.5.3 Obesity & metabolic diseases

Owing to rapid economic transition, urbanisation and the resultant nutrition transition and lifestyle change, high prevalence of overweight and obesity, particularly among adults and urban residents has been documented in South Africa. (34, 42, 44) The prevalence is particularly high in women rather than in men. The 2003 South African Demographic and Health Survey (DHS) found that 30% of adult men and 55% of adult women were either overweight or obese, levels similar to those in the 1998 DHS. (34, 44) While the rural-urban gap in the prevalence of overweight and obesity seems to be maintained in women, the gap may be closing for men: in 1998, 33% of urban and 21% of rural men were overweight or obese, while in 2003 the figures were 31% and 28% respectively. For women in 1998, 57% of urban and 51% of rural women were overweight or obese, while in 2003 the figures were 58% and 49% respectively. (34, 44)

A few studies have also documented overweight/obesity among children and adolescents in South Africa, both at national level and at community level. (33, 35, 46, 47) According to the National Food Consumption Survey in 1999, 17% of children aged 1-9 years were either overweight or obese. A similar study in 2005 indicated that 14% of children in the same age group were either overweight or obese. The prevalence was higher in urban areas in 1999, while in 2005, the gap had closed. (33, 35) Among adolescents aged approximately 13 to 19 years in the South African Youth Risk Behaviour Survey (YRBS) (2002), the prevalence of combined overweight and obesity was

21%. (207) Studies have documented a marked prevalence of overweight and obesity among girls, while on the other hand, prevalence in boys has been relatively low. (46, 47, 153) The prevalence of overweight and obesity in girls compares to that found in several upper middle- and higher-income countries, while that of boys is lower than that found in other countries. (153)

Obesity-related chronic diseases including type 2 diabetes, vascular diseases such as stroke, ischaemic heart disease, and hypertensive diseases and cancers are contributing markedly to the burden of disease in South Africa. (43, 45, 212-214) This burden of disease is applicable to both men and women. Therefore, the earlier held notion following the work of Walker and colleagues (215) that obesity in South African women and adolescent girls was “benign”, has been overtaken by convincing evidence that obesity is associated with the heightened risk of circulatory and other non-communicable diseases, even among Black South African women. (45, 212-214)

Table 3: Prevalence of malnutrition as shown in different studies in South Africa

	Population (n)	**Reference**	**Stunted %**			**Underweight %**			**Wasted %**			**Overweight %**			**Obese %**		
			U	R	N	U	R	N	U	R	N	U	R	N	U	R	N
SAVACG (1994)	6-71 mo (11430)	NCHS/WHO	16	27	23	7	11	9	2	3	3						
NFCS (1999)	1-9 y (2894)	NCHS/WHO IOTF	17	27	22	8	13	10	2	5	4	13	12	12	6	4	5
YRBS (2002)	Approx. 13-19 y (9224)	NCHS/WHO IOTF	-	-	11	-	-	9	-	-	4	-	-	17	-	-	4
DHS (2003)	<5 y (1159)	NCHS/WHO	27	28	27	12	11	12	6	5	5	-	-	-	-	-	-
NFCS 2005	1-9 y (2469)	CDC/WHO IOTF	16	20	18	9	9	9	5	4	4	10	10	10	4	4	4

U=Urban; R=Rural; N=National

Sources:

SAVACG (1994): The South African Vitamin A Consultative Group, 1995 (36)

NFCS (1999): Labadarios et al., 2005 (35)

YRBS (2002): Reddy et al., 2008 (46)

DHS (2003): Department of Health, 2003 (34)

NFCS 2005: Department of Health, 2007 (33)

2.6 Summary

The review of literature has highlighted the extent to which nutrition transition - driven by rapid economic transition, urbanisation, globalisation, technological and social changes, and often

accompanied by decreased physical activity levels - has occurred in LMICs including South Africa. (1, 2, 51) The result is high levels of overweight/obesity particularly among adults despite the unfinished agenda of childhood undernutrition, leading to the double burden of malnutrition, a phenomenon increasingly important in LMICs. (1) In line with the co-existence of undernutrition and obesity, a protracted-polarised model of epidemiologic transition has been documented in LMICs, in which infectious diseases and undernutrition-related diseases coexist with obesity-related non-communicable diseases and persist over prolonged periods of time. (93) Therefore, both undernutrition-related diseases, infectious diseases and obesity-related diseases including type 2 diabetes and cardivascular diseases contribute substantially to the burden of disease in these societies. (9)

Factors that influence both undernutrition and obesity have been identified. In both cases, these factors are organised hierarchically at child, household/familial and community levels. (50)(52, 53) The role of HIV on undernutrition has also been underlined including direct and indirect effects. (25, 28, 30, 118) The role of developmental programming in which poor nutrition early in life may have implications for obesity later in the lifecourse, particularly if there is nutrition abundance later in life, has also been highlighted. (138, 140, 141)

The literature has indicated that ramifications of both undernutrition and overnutrition traverse the lifecourse and are important both at the individual and national levels. (12, 19, 20, 22) Recognising the importance of undernutrition to development, a goal to alleviate it was set among the millenium development goals, whose achievement is currently far from being realised. (22-24)

The review has identified some gaps in research which this study will contribute towards:

- Though childhood and adolescent obesity and risk for metabolic disease are increasingly becoming a public health concern in LMICs, (11) the range of literature on this is limited,

particularly in rural areas.

- The co-existence of childhood undernutrition with adolescent obesity, whose importance is exemplified in developmental programming literature (138, 140, 141) is not well studied.

3.0 Methodology

3.1 Study setting and population

3.1.1 Physical characteristics & infrastructure

This study was conducted in Agincourt sub-district, located in Bushbuckridge district, Mpumalanga Province, northeast South Africa alongside the country's border with Mozambique (Figure 7). Measuring some 402 sq km, and located about 500km northeast of Johannesburg, Agincourt is a rural, semi-arid setting. It was part of the former Gazankulu homeland, hence the land is subdivided into plots too small to support subsistence farming. Despite recent government development initiatives, including electrification, provision of piped water at community level and improved road networks, infrastructure remains limited. Housing material varies from traditional mud houses to brick houses. Limited governent housing is also provided through the rural development programme. Piped water is pumped to reservoirs, then it is mainly reticulated to communal taps where community members, mainly women and children collect it. There are frequent water shortages in most villages. Sanitation is poor, with pit latrines of varying types, from traditional pit latrines to ventilated improved pit latrines, being the main means of sewage disposal. Roads are not tarred and are sometimes in poor condition. There is limited public transport, with the main means of transport being privately-owned taxis. (216-218)

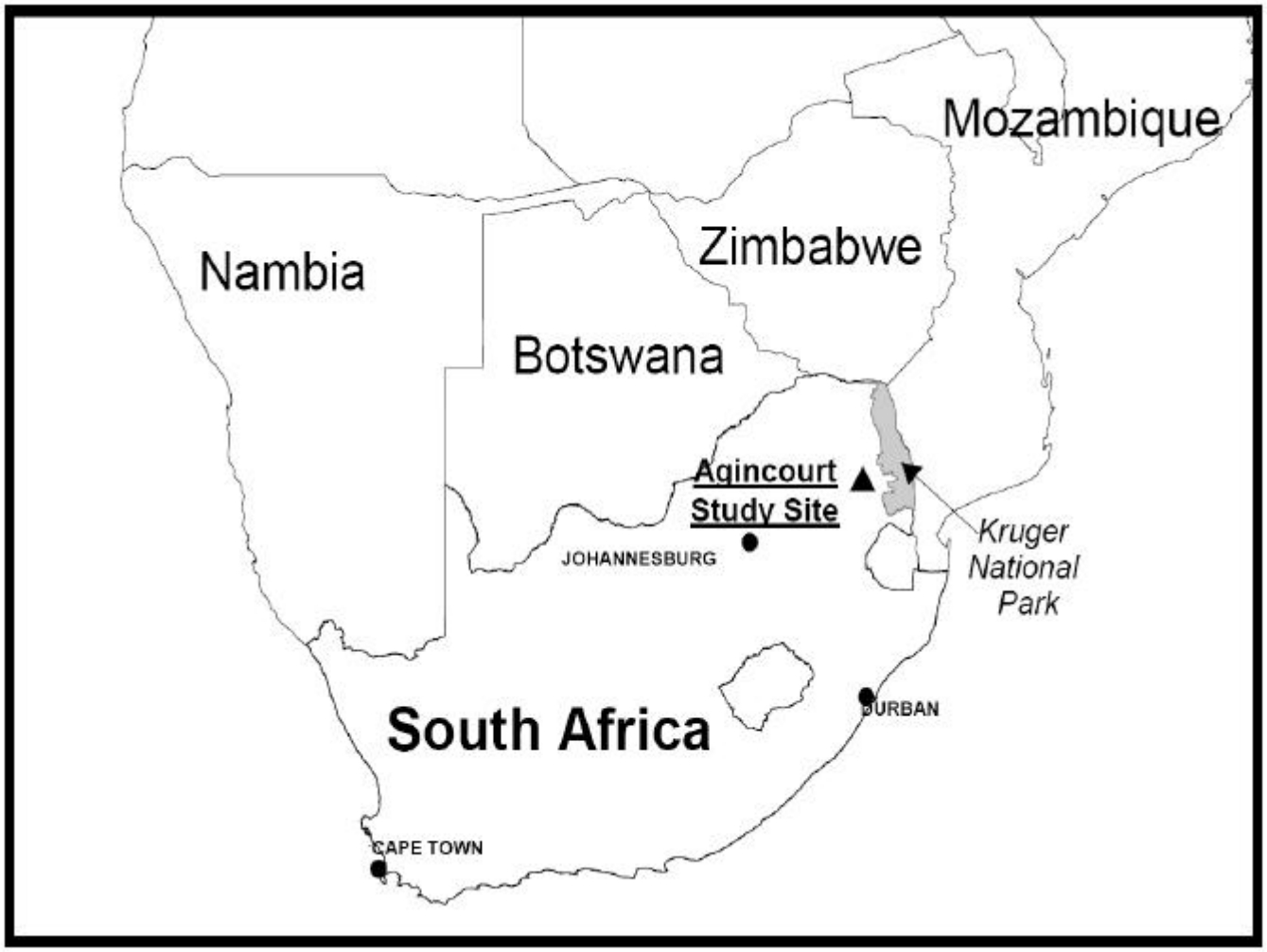

Figure 7: Southern Africa showing Agincourt study site, 2007

Source: Kahn et al (2007)(216)

3.1.2 Demographics

This study was nested within the Agincourt health and socio-demographic surveillance system (HDSS), run by the MRC/Wits Rural Public Health and Health Transitions Research Unit (Agincourt) - referred in this thesis as the MRC/Wits-Agincourt Unit. Established in 1992, the Agincourt HDSS follows some 70,000 people living in 11,700 households in 21 contiguous villages. The population density is slightly over 170 persons per square kilometre. (219) The population mainly comprises Tsonga/Shangaan-Speaking ethnic group. However, about a third of the population are of Mozambican origin - while most entered South Africa as refugees in the

early to mid-1980s following the civil war in Mozambique, some migrated more recently. The Mozambicans are also Tsonga/Shangaan-speaking, have widely intermarried with the host South African population, and share similar cultures. Immediately following migration, they settled in distinctive villages, commonly known as refugee settlements. They were granted group refugee status in 1993. Despite this, and despite the length of time they have been in South Africa, they live with limited legal recognition and integration into society. Close to 90% of all people of former Mozambican origin live in these villages while the rest are integrated in the villages predominantly inhabited by people of South African origin. (216-218)

3.1.3 Socio-economic status

Access to education has improved greatly in the recent past. Each village has a primary school, a total of 28 primary schools and there are several secondary schools, a total of 21 schools. Literacy levels have improved post-Apartheid in the the younger generation aged up to 29 years. However, in the older generation, illiteracy levels are high, reaching levels of almost 80% for those aged 60 years and above. (219)

The area is characterised by high levels of poverty; the province in which the study area is located has one of the highest poverty rates in South Africa, at 64%. (195) There are high levels of unemployment; strict unemployment (excluding underemployment) is estimated at 29% for men and 46% for women. Labour migration is widespread involving up to 60% of working age men and growing numbers of women. Most formally employed people, particularly men work in the mining sector, in security and construction firms of larger towns and in the nearby plantations and game reserves. Women are mainly employed in domestic work and on farms. Another source of local employment is the public sector, including the police and education sectors. Additionally, government support grants including the child support grant and old-age pension, are an important source of income for many families. (198, 219, 220)

3.1.4 Health services & health profile

Health care services are limited: there are five primary care clinics staffed by nurses that provide free services. The clinics refer to a larger public health centre within the study area. The health centre further refers to three district hospitals, 25 to 60 kilometres away. Faith and traditional healers are popular and are often consulted for a wide range of conditions. Anti-retroviral therapy has been available in the district hospitals since late 2005. Further, a public-private community health centre, located in one of the villages, also provides anti-retroviral therapy since 2007.

A health transition with a quadruple burden of disease has been described in Agincourt: the unfinished agenda of poverty-related diseases, particularly severe malnutrition and acute diarrhoea in children; non-comunicable diseases including diabetes, vascular diseases and cancers in older adults; high levels of violence and accident-related injuries; and HIV-related diseases such as TB, particularly in young children and young adults. (212, 213) Overall, mortality has increased since the mid-1990s, accompanied by a rapid decrease in life expectancy of 14 years in males and 12 years in females. The age groups most affected by the rise in mortality are children under five years and young adults aged 20-49 years, with a two- and five-fold increase respectively. (45, 212, 213, 221, 222).

The area is characterised by a high prevalence of HIV/AIDS. Among pregnant women visiting public antenatal health clinics in the province, HIV prevalence is slightly over 30% (37). For the general population aged 2 years and above, the prevalence was 15% in 2005; second highest nationally. (223) The increases in mortality in children and younger adults has mainly been associated with HIV/AIDS and HIV-related diseases such as TB. In the period 2000-2003, 27% of all child deaths, and 34% of male and 47% of female deaths in the 15-49 year age group were

due to HIV/AIDS. Furthermore, a major part of malnutrition-related deaths in children are due to HIV. (45, 213)

3.2 Data and Methods

3.2.1 Data sources

The study uses data from three sources (Figure 8):

- A growth survey (April to July 2007) nested within the Agincourt HDSS

This involved a sample of children aged 1-20 years, randomly selected from the Agincourt HDSS database. It involved anthropometric measurements of children aged 1-20 years, pubertal assessment of adolescents aged 9-20 years, and HIV testing of children 1-5 years.

- A follow-up of a subset of the 2007 growth survey (May to June 2008)

This involved follow-up of HIV positive children aged 1-5 years identified in the 2007 survey, matched with an equal number of HIV negative children.

- The Agincourt HDSS, supplementing data collected in the 2007 growth survey.

The Agincourt HDSS provided explanatory variables for the nutritional status of children aged 1-20 years including individual/child, maternal and household level factors, to supplement data collected in the 2007 survey.

3.2.2 Study samples

Figure 8 shows the different data samples for this study.

3.2.2.1 Growth survey (2007)

The study sample comprised children and adolescents aged 1-20 years, selected from the entire population within this age spectrum, in the Agincourt HDSS as of March 2007; (n=34775; 50%

boys and girls respectively). For analysis and documentation purposes, the ages were truncated to full years; thus, for example, 20 years refers to participants aged 20.0 – 20.9 years. Four thousand children and adolescents were targeted, comprising 100 males and 100 females for each year of age. We oversampled 10-15 children per age-sex group to counter possible non-participation. Thus a total of 4658 children were randomly selected from the Agincourt HDSS database. Only children who had lived in the study area at least 80% of the time since birth, or since 1992 when enrolment in the Agincourt HDSS began were included. A random sample of children was drawn from each age-sex-village stratum in proportion to the population size of the village.

3.2.2.2 Follow-up study (2008)

The sub-sample for the 2008 follow-up study was selected from the the main sample in the growth survey described above. The sub-sample comprised all children (aged 1-5 years in 2007) identified as HIV positive in 2007 (n=35) and one child whose HIV status was indeterminate, matched at the population level for age, sex and village of residence, with an equal number of HIV negative counterparts. Thus, the total number of HIV negative children included was 36. The matching was done with only age, sex and village of residence as including other variables in the matching did not give adequate cases to match.

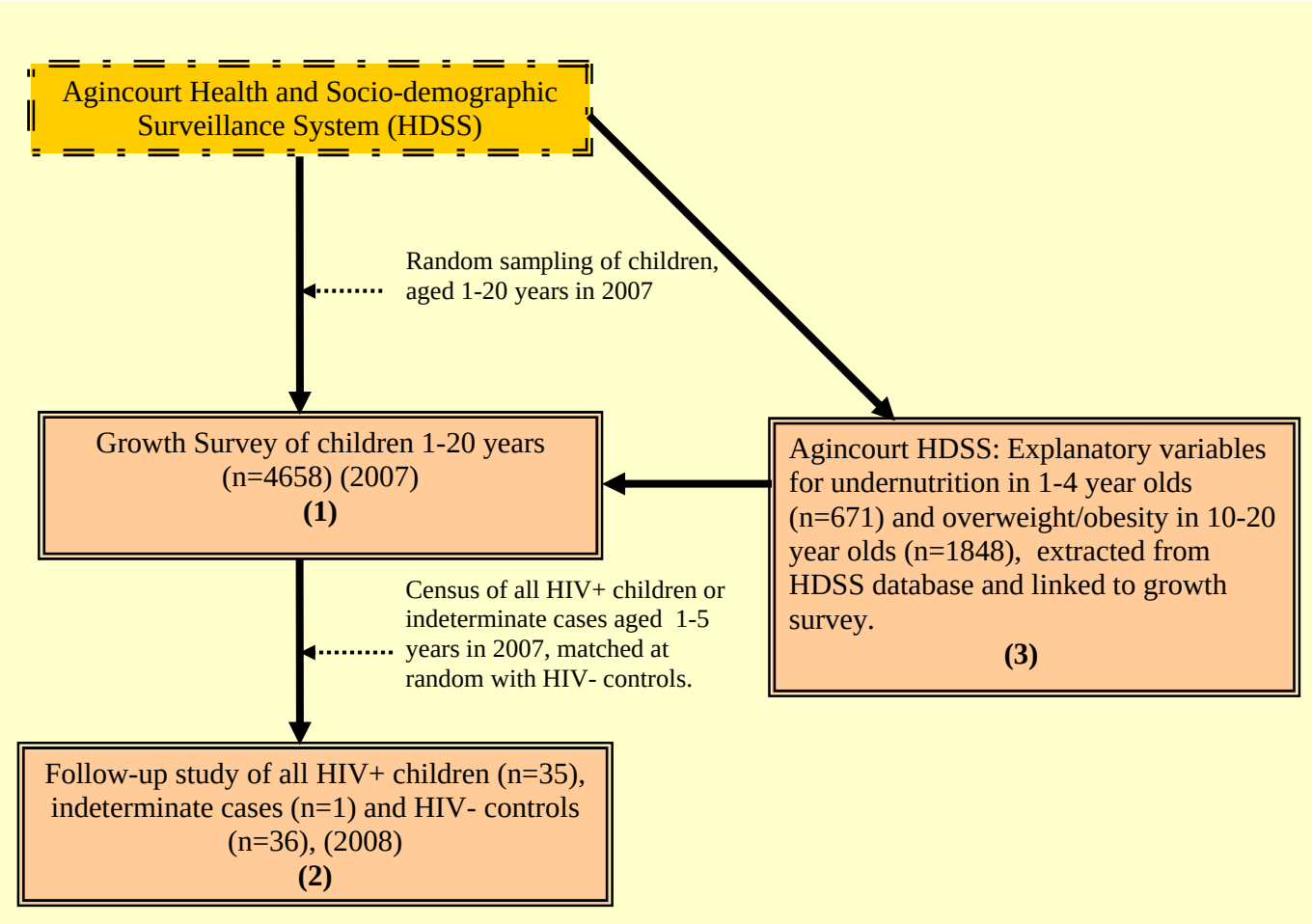

Figure 8: Flow chart showing the three data sets used and their linkages

3.2.3 Ethical considerations

All the three studies providing data for this PhD were approved by the University of the Witwatersrand Committee for Research on Human Subjects (Medical). Ethical clearance numbers are: 2007 Growth Survey-M070244 and M070941; 2008 Follow-up Study-M080330; and Agincourt HDSS-M960720. The fieldworkers were carefully trained on the ethical principles guiding research on human subjects and these were fully respected during the study process. Participation in the various studies was only by those who voluntarily agreed to participate and gave written (2007 growth survey and 2008 follow-up study) or verbal (Agincourt HDSS) consent to participate after the studies were fully explained. Data were anonymised and codes were used in linking the different data sets.

A dedicated office of the MRC/Wits-Agincourt Unit: the LINC (Learning, Information dissemination and Networking with Communities) Office plays a major role in mobilising the community in which the Agincourt HDSS is conducted. Before commencement of any project in the study community, the LINC office holds a series of meetings with the community and civic and traditional community leaders. Service providers including health professionals, HIV counsellors and agriculatural officers attend these meetings. The meetings are aimed at informing the community of the up-coming project and to obtain community consent for the project before going to household level. Further, after every Agincourt HDSS census update round, feedback sessions are held with community members and leaders to present the main findings of the HDSS and other nested studies. Printed village fact sheets are also prepared. Main findings are disseminated to provincial and national departments of health to inform policy. In line with the Unit's practice, community members, community leaders and health facility staff were duly mobilised at the beginning of the the 2007 and 2008 studies. Feedback for the study findings was given at a later date.

Children and adolescents who were malnourished during the 2007 survey and the 2008 follow-up were referred to local health facilities for further investigations and nutritional support. Caregivers of children found to be HIV positive were counselled on-site and referred to health facilities for further counselling as well as investigations including confirmatory tests and support. They were also referred to community-based support groups who had been mobilised at the start of the study.

3.2.4 Data collection

3.2.4.1 Growth Survey (2007)

Data collection procedures

Data collection involved anthropometric measurements for all study participants aged 1-20 years, pubertal assessment for adolescents 9-20 years and HIV testing for children aged 1-5 years. Participants were invited to data collection camps over the weekends and holidays at centrally located schools within each study village.

A team of 12 fieldworkers was carefully trained by experts in anthropometric measurements from the Birth to Twenty Programme, located in Johannesburg South Africa. All the fieldworkers were trained on all the anthropometric techniques to start with. Coefficient of variation for the various anthropometric measurements was determined for each fieldworker after the training. The best fieldworkers for each measurement were determined and given time to practice taking that measurement. Coefficient of variation on specialised measurement was then determined for the respective field worker before field work began. To minimise fieldworker variation, each field worker specialised in a specific measurement and collected that data on all study participants during fieldwork. The coefficient of variation towards the end of fieldwork ranged between <1% and 3% for the different anthropometric measurements.

The two fieldworkers conducting HIV testing were carefully trained on the HIV test procedures and on HIV counselling by research nurses trained in paediatric HIV testing and VCT. Likewise, the two fieldworkers; one male and one female, conducting the pubertal assessent were also carefully trained on the Tanner pubertal staging procedures as well as privacy, by experts from the Birth to Twenty Programme.

The fieldwork team comprised experienced fieldworkers from the Agincourt HDSS, thus were familiar with data collection procedures. The team was supervised by a supervisor and the author, who was the project site manager. A data quality clerk ensured quality of data collected by checking completeness and accuracy of data on-site. Further, the author edited all the completed data collection tools on a daily basis to ensure accuracy of the data.

Written informed consent was obtained from the caregiver of children aged 1-17 years (caregiver in this study refers to child's primary caregiver, either biological mother or other carer (such as grandmother or other relative) and from adolescents 18-20 years themselves, while assent was also obtained from those aged 9-17 years.

Anthropometric measurements

Anthropometric measurements including height, weight and waist circumference were carried out on all children and adolescents aged 1-20 years. Height was measured using a stadiometer (Holtain, UK) calibrated in millimeters. For all children aged less than 24 months, the determination of length was done using an inelastic tape measure (Holtain, UK), in a recumbent position on a flat surface. Weight in kilograms (to one decimal point) was determined using a mechanical bathroom scale (Hanson, UK). For children aged less than two years who were unable to stand by themselves, the weight of the caregiver was taken first, then the weight of the caregiver together with the child; and then the weight of the child was obtained from deducting the former from the latter. Waist circumference was measured in milimetres using an inelastic tape measure (Holtain, UK), at the natural waist, i.e. midway between the tenth rib and the illiac crest, with the participant in a standing position. All measurements were according to standard procedures. (224)

Pubertal assessment

Pubertal assessment in children/adolescents 9 years and above was done using the Tanner 5-point pubertal self-rating scale. (225) The self rating scale has been validated among Black South Africans, (226) and in several other settings, (227) but not in others. (228, 229) This self-administered questionnaire was conducted for males and females separately, with the assistance of same-sex interviewers who explained how to do the assessment prior to the participants completing the questionnaire. The five Tanner stages reflect physical development based on external primary and secondary sex characteristics: pubic hair in girls and boys, breast development in girls and genitalia in boys. (225) Genital development in boys and breast development in girls were used to define the stages in this study.

HIV testing

HIV testing of children aged 1-5 years was carried out. Informed consent for the HIV test was obtained separately from that given earlier for anthropometric measurements. Pretest counselling was given to the mother/caregiver of the child before the test was performed. Blood was obtained from each child through a finger prick. Two rapid tests: Uni-Gold^{TM} (Trinity Biotech, Bray, Ireland) and Determine^{TM} (Abbott, Wiesbaden, Germany) were taken concurrently in accordance with WHO recommendations for HIV screening in children. (230) A child was defined as HIV negative if both the Unigold and Determine tests were negative, HIV positive if both tests were positive, and indeterminate if either of the tests was negative and the other positive. Post-test counselling was given to all the mothers. For those whose children were HIV positive, they were informed they may potentially be HIV positive themselves and hence were advised to go for their own HIV test. The result was given to the caregiver if s/he wished to know the status, but caregivers were encouraged to take the results. Referral for further investigations including confirmatory test, counselling and support and HIV test for the mother was done for those who tested HIV positive on any of the two HIV tests.

3.2.4.2 Follow-up study (2008)

Data collection procedures

Data was collected at households following written informed consent from the caregiver. The study involved both quantitative and qualitative methods. Field work was conducted by three fieldworkers, one female, two males, whose first language was Tsonga and were residents of the study area. They were carefully trained on qualitative data collection and on the specific study objectives before beginning field work. Role plays followed by pilot interviews ensured clear understanding of questions. Although the author was not a Tsonga speaker and could not conduct interviews, she accompanied the research assistants in the field throughout the data collection period.

A semi-structured questionnaire was administered to all caregivers of both HIV positive and HIV negative children. The questionnaire included open-ended questions on a child's health status, health seeking, feeding, and socio-demographic details of the caregiver (see appendix 1). Child's weight was taken, measured in kilograms (to one decimal point) using a mechanical bathroom scale (Hanson, UK). Indepth interviews were conducted with caregivers of HIV positive children who knew the child's status (n=22). Issues explored in the in-depth interviews included attitudes and reactions to knowing HIV status of the child, the impact of knowing a child's positive HIV status on caregiving to the child, antiretroviral treatment-seeking for the child, views on treatment and services available in the community for HIV positive children, challenges in caregiving and coping strategies and support networks for caregivers (see appendix 1).

The semi-structured questionnaire and in-depth interview guide were translated by first language Tsonga-speakers, i.e. from English to Tsonga, then retranslated to English by an independent person. The backtranslation enabled the author, who is not Tsonga-speaking, to ensure that the

meaning of questions was not lost in the translation. The semi-structured questionnaire was administered first, with an appointment made for an in-depth interview on a different day. Weight was taken whenever the child was available on either of the visits. Daily debriefing sessions were held between the author and the field workers to discuss issues and themes emerging from the interviews and to ensure consistency of meaning to questions. New issues and emerging themes were explored in subsequent interviews. All interviews were conducted in Tsonga, and were tape-recorded. The questionnaire took about 20-30 minutes, while in-depth interviews took between 45 minutes to 1.5 hours to complete.

Informal group discussions with home based care groups (n=5) and a Community Advisory Group (n=1) provided information to explain findings from the semi-structured quationnaires and in-depth interviews. These dealt with factors affecting nutritional status of children and adolescents and on the care of HIV positive children in the community. Discussions were held during community mobilisation and feedback sessions. The discussions were moderated by the author in English because most of the participants understood and spoke English; a first- language Tsonga speaker served as an interpreter whenever necessary.

3.2.4.3 Agincourt HDSS

Data collection procedures

The Agincourt HDSS is a longitudinal community surveillance that involves systematic annual recording of vital demographic events including births, deaths and in- and out-migrations occuring in the entire Agincourt sub-district. The system uses digitised geo-referenced village maps for locating households, updated every year to take into account spatial changes. The baseline census was conducted in 1992 and data is updated every year; vital demographic events are captured at each update. Additional data to provide information on particular areas of interest is

collected as special census modules nested within the annual update rounds. These include education, child social grant uptake, health care utilisation, union status and food security, among others. An asset survey conducted in each household every two years gives a measure of household socioeconomic status. A verbal autopsy, using locally validated instruments (231) is conducted on event of each death to determine the probable cause.

Data collection involves annual household visits by carefully trained fieldworkers who are well supervised by an experienced field supervisor. The census update is conducted by four teams each comprising five to six fieldworkers and a team supervisor. The interview is done with the most senior member of the household available at the time of the interview who should be an adult, knowledgeable about all household members and events. The fieldworkers use field maps to locate households.

On a daily basis, the fieldworkers themselves check all data collected. Fellow field workers cross-check each other's work on a weekly basis. Field supervisors do spot checks and duplicate visits on 2% of the households. Errors observed at these levels are corrected at the field office where possible, wih a revisit to the household when necessary. After this, a specialised data quality control clerk reviews the completed data collection tools, records all errors and sends back the tools with remaining errors to the field for correction.

Verbal informed consent is obtained before the interview. Further details on the Agincourt HDSS are provided elsewhere. (216, 232)

Data extraction

Data on potential explanatory variables was extracted from the Agincourt HDSS and linked to the growth survey data by a unique identity number. This data was collected/updated in 2007 and

includes:

- Individual/child level: child's age, sex, birth weight and relationship to household head
- Maternal level: mother's age, nationality, highest education level, marital/union status, co-residence with child and place of delivery (for index child)
- Household level: household head's age, sex and highest education level, household food security and food consumption and social economic status
- Community level: area of residence as a proxy for community level factors

3.2.5 Data quality control

3.2.5.1 Growth survey (2007)

A rigourous data cleaning and quality check exercise was undertaken on the captured data. The author did a 10% cross-check of all the entered data against the data collection form at random. A handful of systematic errors in data entry were discovered which were corrected in the data base for all the participants. A few non-systematic errors were also discovered but these were minimal (0.4%). This informed thorough cleaning of the data including checking seemingly erroneous values against the form. The errors that were associated with data entry were corrected, while cases with errors at field level were dropped (n=1).

3.2.5.2 Follow-up study (2008)

Data cleaning for quantitative data involved checking for erroneous values against the data collection tool and correcting as necessary. For the qualitative data, transcription of interviews was done in Tsonga then translated to English so that the author could clarify issues with a third party whenever in doubt. Cleaning involved retranslation or re-transcription and/or confirming with a third party of any data that was not clear or seemed erroneous. When in doubt, the translator consulted with other fieldworkers.

3.2.5.3 Agincourt HDSS

In the Agincourt HDSS, data is routinely entered through an MS SQL Server relational database management system. There are programmed validation checks to flag and filter erroneous data. Additionally, routine data cleaning of captured data is done by data managers. Errors are sent back to the field for correction. This ensures consistency, accuracy and completeness of the data.

3.2.6 Data analysis

3.2.6.1 Quantitative methods

Measures

Table 4 below shows the study variables and the respective data sources.

Outcome measures

As shown in Table 4, outcome measures were derived from the 2007 growth survey and included HAZ, WAZ, WHZ, stunting, underweight, wasting, BMI, waist circumference, waist-to-height ratio, overweight, obesity and risk for metabolic disease (central obesity).

HAZ, WAZ, WHZ were generated using the WHO Anthro 2005 programme, Beta Version. (233) Z-scores for children up to 60 completed months were generated using the WHO 2006 growth standards while for those aged 5-17 years were determined using the NCHS/WHO reference. For the WHO standards, weight-for-length standards range from 45 to 110cm (for children aged younger than 24 months) while weight-for-height standards (for children 24-60 months) range from 65 to 120cm for both sexes. For the NCHS/WHO reference, weight-for-length reference ranges from 49 to 103cm and weight-for-height 55 to 145cm for boys (up to 11 years approximately); while for girls, weight-for-length reference ranges from 49 to 101cm and weight-for-height 55 to137cm (up to 9 years approximately). Thus, for the purpose of

comparisons by sex, WHZ scores were calculated for all children up to 9 years. Stunting, underweight, and wasting were respectively defined as z-scores less than -2. (57, 66)

BMI was determined by dividing weight (in kg) by height squared (in metres). Overweight and obesity in children 2-17 years was determined using the absolute age and sex-specific cut-offs for BMI recommended by the IOTF. (71) These are defined to pass through a BMI of 25 and 30 kg/m^2 at 18 years of age, for overweight and obesity respectively. For adolescents 18-20 years, adult cut-off points of BMI =25 and =30 kg/m^2 for overweight and obesity respectively were used. (70)

Waist circumference was used as a continuous variable in the regression analysis. Waist-to-height ratio was generated by dividing waist circumference by height. Waist circumference and waist-to-height ratio cut-offs were used to determine those at risk of metabolic disease (also referred to as central obesity in this thesis) among adolescents, who had attained at least Tanner stage 3, as it was assumed that these participants were approaching approximately adult height. However some growth in stature may still happen as the adolescents go through the various pubertal stages. (234) Waist circumference cut-offs of =94cm for males and =80cm for females (72) and waist-to-height ratio of 0.5 for both sexes (73) were used.

Explanatory variables

As shown in Table 3, explanatory variables were mainly derived from the Agincourt HDSS dataset and included individual/child, maternal, household and community level characteristics as described above. Additionally, a child's HIV status and mother's place of delivery (for those aged less than five years) and pubertal development status (for adolescents), were derived from the 2007 growth survey.

Construction/definition of most of the variables for inclusion as explanatory variables in the regression analysis is self explanatory, as stipulated in Table 3 below. Food insecurity was defined as having reported insufficient food to eat either in the last one month or in the last one year, whereas food-secure households were characterised as households reporting sufficient food to eat both in the last one month and one year respectively. The household wealth index was constructed from the asset survey, (235) which documented type and size of dwelling; water and sanitation facilities; electricity; modern assets such as fridge and television; transport assets such as bicycle and car; communication assets such as a cellphone; and livestock such as cattle. A summated absolute score for the wealth indicator was constructed. To begin, each asset variable was coded with the same valence (i.e. increasing values correspond to greater socio-economic status) and effectively given equal weight by rescaling so that all values of a given asset variable fall within the range [0, 1]. Assets were then categorized into five broad groups – 'modern assets', 'livestock assets', 'power supply', 'water and sanitation' and 'dwelling structure'. For each household within each asset group, the rescaled asset values were summed up and then rescaled again to yield a group-specific value in the range [0, 1]. Finally for each household, these five group-specific scaled values were summed to yield an overall asset score whose value could theoretically fall in the range [0, 5]. Household wealth index tertiles (3 categories) were generated from the absolute score and labelled as most poor (lowest 1/3), middle, and least poor (highest 1/3). A composite measure was used in the analysis rather than using the five different dimensions of wealth status as these dimensions are highly correlated. Additionally, it is easier to interpret the effect of the composite measure rather than five diffferent dimesnsions.

Table 4: Study variables

Variable & category values	Variable type & category definition	Data Source
Dependent Variables		
HAZ	Continuous	Growth
WAZ	Continuous	Growth & Follow-up
WHZ	Continuous	Growth
Stunting	Categorical	Growth
0	No (HAZ <-2)	
1	Yes (HAZ =-2)	
Underweight	Categorical	Growth
0	No (WAZ <-2)	
1	Yes (WAZ =-2)	
Wasted	Categorical	Growth
0	No (WHZ <-2)	
1	Yes (WHZ =-2)	
BMI	Continuous (kg/m^2)	Growth
Overweight	Categorical	Growth
0	No (2-17 years, IOTF cut offs[c]; = 18 years BMI < $25kg/m^2$)	
1	Yes (2-17 years, IOTF cut offs; = 18 years BMI = $25kg/m^2$)	
Obese	Categorical	Growth
0	No (2-17 years, IOTF cut offs; = 18 years BMI <$30kg/m^2$)	
1	Yes (2-17 years, IOTF cut offs; = 18 years BMI = $30kg/m^2$)	
Waist circumference	Continuous (cm)	Growth

Table 4: Study variables

Central obesity	Categorical	Growth
0	No (WC <94cm for males & <80cm for females or WHtR<0.5)	
1	Yes (WC =94cm for males & =80cm for females or WHtR =0.5)	
Independent variables		
Child level		
age	Continuous (years)	Agincourt HDSS
Sex	Categorical	Agincourt HDSS
0	Boys	
1	Girls	
Pubertal status	Categorical	Growth
0	Pre-pubertal (Tanner stage <2)	
1	Pubertal (Tanner Stage 2 to 5)	
Birth weight	Categorical	Agincourt HDSS
1	Low (<2.5 kg)	
0	Normal (=2.5 kg)	
HIV status	Categorical	Growth
0	Negative	
1	Positive	
2	Unknown status	
Relationship to HHH[a]	Categorical	Agincourt HDSS
0	Parent	
1	Grandparent	
2	Other relative	

Table 4: Study variables

Maternal Characteristics		
Age (childhood undernutrition)[b]	Categorical	Agincourt HDSS
1	15-24	
0	25-34	
2	35+	
Age (adolescent obesity) [b]	Categorical	Agincourt HDSS
1	15-34	
0	35-49	
2	50+	
Mother's Nationality	Categorical	Agincourt HDSS
0	South African	
1	Mozambican	
Mother's Education	Categorical	Agincourt HDSS
0	None	
1	Some education < completed Secondary	
2	Secondary & Tertiary	
Mother Union Status	Categorical	Agincourt HDSS
0	Currently in union	
1	Not in union	
Mother co-residence	Categorical	Agincourt HDSS
0	Co-residing	
1	Not co-residing (dead or elsewhere)	
Delivery place	Categorical	Growth
0	Health facility	
1	Home	

Table 4: Study variables

Household Characteristics		
HHH age (childhood undernutrition)	Categorical	Agincourt HDSS
1	15-34	
0	35-49	
2	50+ years	
HHH age (adolescent obesity)	Categorical	Agincourt HDSS
0	15-49	
1	50 +	
HHH Sex	Categorical	Agincourt HDSS
0	Male	
1	Female	
HHH Education	Categorical	Agincourt HDSS
0	None	
1	Some education < completed secondary	
2	Secondary & Tertiary	
Food Security	Categorical	Agincourt HDSS
0	Enough	
1	Not enough	
SES Tertiles	Categorical	Agincourt HDSS
0	Most poor	
1	Middle	
2	Least poor	
Area of Residence	Categorical	Agincourt HDSS
0	Mainly South African village	
1	Mainly Mozambican village	

[a]HHH=Household head; [b]Different maternal age categories were used for children <5 years and adolescents 10-20years because as expected, the age ranges of their mothers were very different; [c]Age and sex-specific cut-offs using IOTF criteria

Statistical analysis

Descriptive and analytic data analyses were done using Stata version 10.0 (StataCorp LP, College Station, Texas, USA). Initial checks on the data were undertaken before analysis. Where parametric statistics were used, test for normality was done to ensure that data were normally distributed before analysis. Where continuous variables were used in regression analysis, test for linearity was done.

Descriptive analysis:

Mean HAZ, WAZ, WHZ, BMI, and their 95% confidence intervals were described. Patterns of stunting (HAZ <-2), underweight (WAZ <-2), wasting (WHZ <-2), overweight and obesity for 1-20 year olds by age and sex, overweight and obesity by pubertal stage and sex for adolescents aged 9-20 years, and central obesity by age and sex for adolescents in Tanner stages 3-5 were described. The Student t-test and one way anova were used to test for differences between means across age-sex groups and by HIV status (for children 1-4 years); and the chi-square test for differences in proportions by sex and age and by HIV status (for children 1-4 years). Non-parametric tests were used to test for differences by HIV status in the 2008 follow-up sample (given the small sample size): the Mann-Whitney test for difference in means of z-scores by HIV status, and Wilcoxon signed-rank test for difference in means of matched pairs (HIV positive children in 2007 vs. 2008 and HIV negative children in 2007 vs. 2008).

Analytic analysis

Linear and logistic regression analyses were done with the outcome and explanatory variables described above. Univariate analysis was done first with all explanatory variables of interest followed by multivariate regression analysis. Only explanatory variables found to be significantly associated with the outcome variable at the 10% level of significance in the univariate analysis were included in the multivariate regression analysis. Test for collinearity among the variables included in the multivariate analysis was done. Additionally, interaction was tested between various variables

with a p-value <0.10 at the univariate level. Multivariate linear and logistic regression analysis was done to determine predictors of undernutrition in children 1-4 years, and predictors of overweight/obesity and risk for metabolic disease for adolescents aged 9-20 years. Missing values for each variable were allocated an independent category in the regression models to maintain all participants in the analysis. Significant association was determined at the 5% level of significance and 95% confidence interval.

3.2.6.2 Qualitative methods

Data Processing

Transcription of interviews was done in the local language (Tsonga) and then translated to English by a local first-language Tsonga speaker. A coding scheme, detailing the coding nodes and hierarchical structure was developed for use in data coding of the transcripts in NVIVO 8 software (QSR International Pty Ltd, Doncaster, Victoria, Australia). Transcribed word files were imported into NVIVO 8 software for coding.

Data analysis

Themes were developed from relevant literature and from women's narratives. Preliminary analysis occurred concurrently with the continued administration of interviews, to identify emergent themes to pursue in subsequent interviews. (236) Interview text analysis was inductive. The primary codes were identified by the author; following this, meta-codes were identified, with attention to contradiction and diversity of experience and attitudes. The codes were reviewed and discussed with a qualitative expert (co-author in Paper III), to ensure appropriate interpretation of the data and consistency. Analysis across all transcripts was conducted using a constant comparative method, to identify themes and their repetitions and variations. (237, 238)

4.0 Results

This chapter presents results of the study in accordance with the three thesis themes and referring to the four thesis papers (Table 1). To begin with, general background characteristics of the study participants are presented.

4.1 General characteristics of study participants

Nearly 80% (3511 participants) of the randomly selected sample participated. Non-participation was due to failure to present for measurements after giving consent (9%), refusal to consent (1%), absence due to being in boarding school (8%), out-migration from study area (3%) and other reasons (3%). From the 3511 participants, 22 were excluded from the analysis: pregnant adolescents (n=9), severely mentally and physically disabled children (n=11), one case with spurious date of birth and one case with erroneous measurements. A total of 3489 children were thus included in the analysis; 1724 (49.4%) males and 1765 (50.6%) females, aged between 1-20 years. The distribution of study participants by sex and age is shown in Paper I, Table 1.

The distribution of adolescents 9-20 years by Tanner pubertal staging is shown on Paper I, Table 2. Most boys were in stages 1 and 2 while most girls were in stages 3-5. Only 5% of boys had reached stage 5.

4.2 Patterns of malnutrition

This section presents the patterns of co-existence of undernutrition with overweight and obesity and risk for metabolic disease among children and adolescents in the study group by age and sex and Tanner stage for adolescents. Analyses involve a total of 3489 children; 1724 (49.4%) males and 1765 (50.6%) females, aged between 1-20 years. Results in this section are mainly presented in Paper I.

4.2.1 Undernutrition

4.2.1.1 Height-for-age z-scores

Patterns of HAZ by age category and sex are presented in Figure 9. Mean height-for-age z-scores were low in children aged 1-4 years at -1.0 (95% CI -1.1 to -0.9). The mean went up in the other categories to stabilise between -0.4 and -0.6. There was no significant difference by sex in the mean z-scores in the younger children aged 1-4 years. However, in the subsequent age categories, girls had significantly higher z-scores than boys ($p=0.002$, $p<0.001$ and $p=0.001$ respectively) (Figure 9). With regards to age-specific differences (Table 5), boys had significantly lower z-scores at ages 5, 6, 14, 15 and 16 ($p<0.05$, respectively).

4.2.1.2 Weight-for-age z-scores

Mean WAZ was 0.5 (95% CI -0.6 to -0.5) in children aged 1-4 years, slightly higher in boys than in girls, but declined in boys in subsequent age-categories while the reverse was true for girls. Like in HAZ, there was no significant difference by sex in the mean z-scores in the younger age category (1-4 years). However, in the subsequent age categories, girls had significantly higher z-scores than boys ($p=0.003$ and $p<0.001$ respectively) (Figure 9). With regards to age-specific differences (Table 5), boys had significantly lower z-scores at ages 5, 7, 12-17 ($p<0.05$, respectively).

4.2.1.3 Weight-for-height z-scores

Mean weight-for-height z-scores declined from an average of -0.1 (95% CI -0.2 to 0.1) in children aged 1-4 years to -0.5 (95% CI -0.6 to -0.4) in children aged 5-9 years. There was no significance difference by sex in the mean z-scores in both age categories. With regards to age-specific differences (Table 5), there was no difference between boys and girls apart from at age 2 where boys had significantly higher z-scores ($p=0.009$).

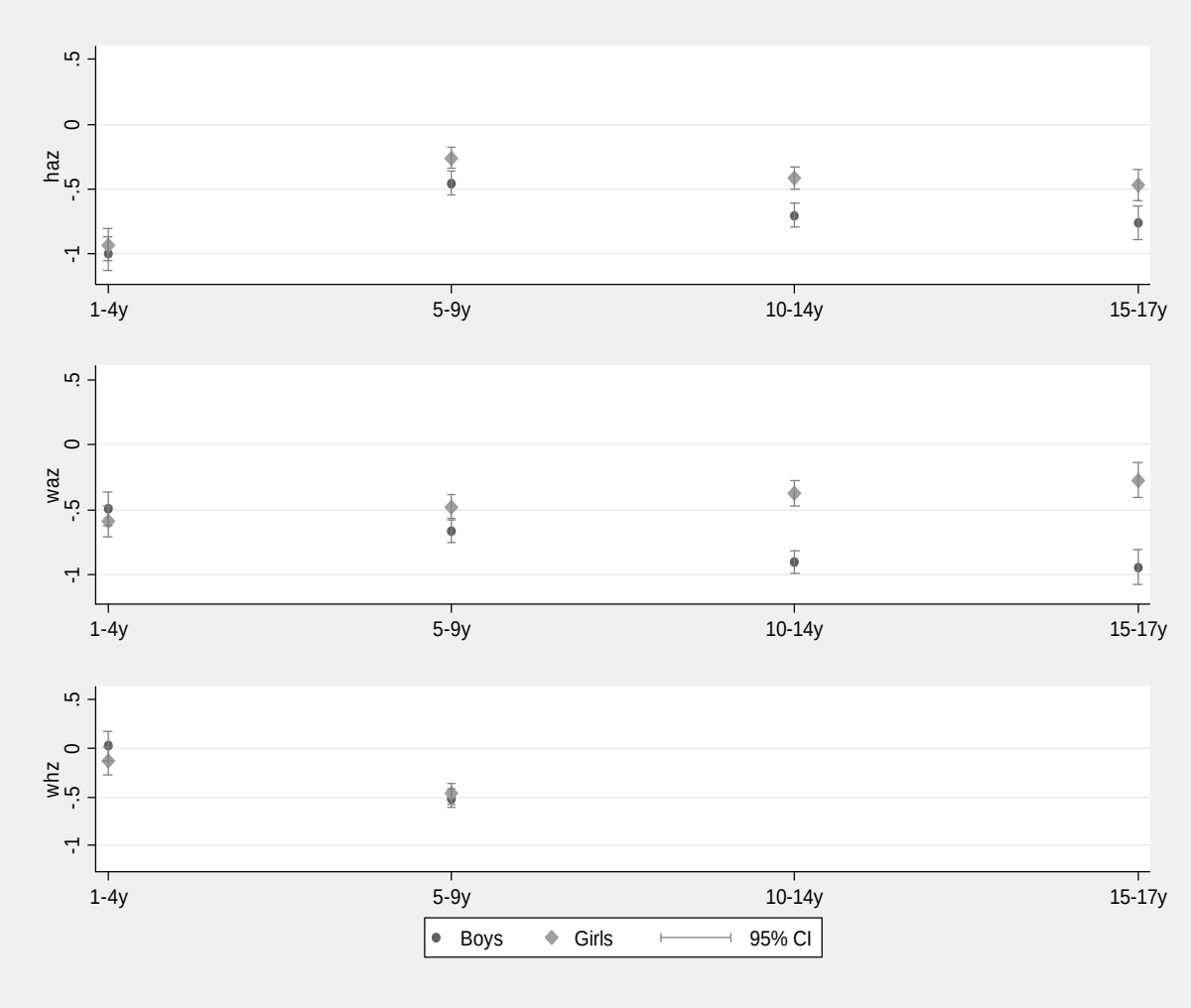

Figure 9: Height-for-age, weight-for-age and weight-for-height z-scores by sex and age category for children aged 1-17 years, Agincourt, South Africa, 2007

Table 5: Height- and weight- for age z-scores for children aged 1-17 years and weight for height z-scores for children aged 1-9 years by sex, Agincourt, South Africa, 2007.

(Significant difference by sex: *p<0.05, **p<0.01, ***p<0.001)

Age (mean)	(N)		HAZ Mean (95% CI)		WAZ Mean (95% CI)		WHZ Mean (95% CI)	
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
1(1.6)	70	67	-1.5 (-1.8 to 1.1)	-1.2 (-1.5 to -0.8)	-0.5 (-0.9 to -0.2)	-0.2 (-0.5 to 0.1)	0.1 (-0.2 to 0.5)	0.5 (0.1 to 0.8)
2(2.5)	83	77	-1.3 (-1.5 to -1.0)	-1.1 (-1.4 to -0.9)	-0.6 (-0.8 to -0.3)	-0.9 (-1.2 to -0.7)	0.1** (-0.2 to 0.4)	-0.4 (-0.7 to -0.2)
3(3.5)	103	91	-0.7 (-1.0 to -0.5)	-0.8 (-1.0 to 0.6)	-0.4 (-0.6 to -0.2)	-0.5 (-0.8 to -0.3)	0.01 (-0.2 to 0.3)	-0.1 (-0.4 to 0.2)
4(4.5)	82	98	-0.6 (-0.9 to -0.4)	-0.7 (-0.9 to -0.5)	-0.5 (-0.7 to -0.2)	-0.7 (-0.8 to -0.5)	-0.1 (-0.4 to 0.2)	-0.3 (-0.6 to -0.1)
5(5.5)	87	86	-0.7*** (-1.1 to -0.6)	-0.1 (-0.4 to 0.03)	-0.9** (-1.1 to -0.6)	-0.4 (-0.6 to -0.2)	-0.5 (-0.8 to -0.3)	-0.5 (-0.7 to -0.2)
6(6.5)	104	94	-0.5* (-0.7 to -0.3)	-0.2 (-0.4 to -0.0)	-0.7 (-0.9 to -0.5)	-0.4 (-0.7 to -0.2)	-0.5 (-0.7 to -0.2)	-0.5 (-0.8 to -0.3)
7(7.5)	91	110	-0.4 (-0.6 to -0.2)	-0.2 (-0.4 to 0.0)	-0.7* (-0.9 to -0.5)	-0.3 (-0.5 to -0.1)	-0.5 (-0.7 to -0.3)	-0.4 (-0.6 to -0.2)
8(8.6)	111	97	-0.3 (-0.4 to -0.1)	-0.4 (-0.5 to -0.2)	-0.6 (-0.7 to -0.4)	-0.6 (-0.8 to -0.4)	-0.5 (-0.7 to -0.4)	-0.5 (-0.7 to -0.2)
9(9.5)	90	100	-0.3 (-0.5 to -0.1)	-0.3 (-0.5 to -0.2)	-0.6 (-0.8 to -0.4)	-0.6 (-0.8 to -0.5)	-0.6 (-0.7 to -0.4)	-0.6 (-0.8 to -0.3)
10(10.5)	98	101	-0.5 (-0.7 to -0.3)	-0.3 (-0.5 to -0.1)	-0.7 (-0.9 to -0.6)	-0.5 (-0.7 to -0.2)		
11(11.5)	105	97	-0.6 (-0.8 to -0.4)	-0.3 (0.6 to -0.1)	-0.8 (-1.0 to -0.6)	-0.5 (-0.8 to -0.3)		
12(12.5)	96	89	-0.8 (-0.9 to -0.6)	-0.5 (-0.7 to -0.3)	-0.9*** (-1.1 to -0.7)	-0.3 (-0.5 to -0.1)		

13(13.5)	94	97	-0.8	-0.6	-1.0***	-0.3
			(-1.0 to -0.5)	(-0.8 to -0.4)	(-1.2 to -0.7)	(-.5 to -.2)
14(14.5)	78	89	-0.9***	-0.3	1.1***	-0.2
			(-1.1 to -0.7)	(-0.5 to -0.1)	(-1.4 to -0.9)	(-0.4 to 0.1)
15(15.5)	82	99	-0.9*	-0.5	-0.9***	-0.3
			(-1.1 to -0.7)	(-0.7 to -0.3)	(-1.2 to -0.7)	(-0.5 to -0.1)
16(16.5)	74	94	-0.7*	-0.4	-0.9***	-0.4
			(-1.0 to -0.5)	(-0.6 to -0.2)	(-1.1 to -0.7)	(-0.6 to 0.2)
17(17.5)	69	67	-0.6	-0.5	-1.1***	-0.1
			(-0.9 to -0.4)	(-0.7 to -0.2)	(-1.3 to -0.8)	(-0.4 to -0.2)

4.2.1.4 Stunting

Stunting was prevalent in the study group, particularly in children aged 1-4 years, (18%) (Table 6). The prevalence was highest in children aged 1 year, at 32%, but fell in subsequent years to plateau at approximately 3-6 % from 5 years onwards, before rising again in boys during adolescence between ages 14 and 15 years when the prevalence rose to 14-15% (Paper I, Figure 1). There was no significant sex difference in stunting in the 1-4 years age category. Stunting was significantly higher in boys than in girls in all the other age groups ($p<0.05$ respectively) (Figure 10). With regards to age-specific differences, stunting was significantly higher in boys than girls at 6, 14 and 15 years ($p<0.05$ respectively). With regards to stunting by Tanner stage for adolescents aged 9-20 years (Paper I, Figure 2) stunting was highest at Tanner stage 1 for both girls and boys at an average of 9% and reduced with increasing stage to about 1% at Tanner stage 5. There was no significant difference in stunting by sex in the various Tanner stages.

4.2.1.5 Underweight

As Table 6 shows, the prevalence of underweight 10% for children aged less than five years, going down to between 6-8% in the other age groups. As Figure 10 shows, there was no sex difference in

children aged 1-4 years, but it was significantly higher in boys compared to girls during adolescence in both age categories 10-14 and 15-17 years ($p<0.001$ and $p=0.001$ respectively). With regards to age-specific differences, the prevalence of underweight peaked in boys aged 14 years at 19%, and was significantly higher in boys than in girls at ages 5, 13, 14 and 15 ($p<0.05$, respectively). (Paper I, Figure 1). With regards to Tanner pubertal stages (Paper I, Figure 2), boys at Tanner stages 2 and 3 were significantly more underweight than girls in the same stage at 11% vs. 4% ($p=0.008$) and 10% vs. 2% ($p=0.001$) respectively. There was no underweight at all in both boys and girls in Tanner stage 5.

4.2.1.6 Wasting

The prevalence of wasting was 7% and 6% in children aged less than five years and those aged 5-9 years respectively (Table 6). There was no difference by sex across the different age categories (Figure 10), and also with regards to age-specific categories (Paper I, Figure 1).

Table 6: Prevalence of stunting, underweight and wasting by age categories for children aged 1-17 years, Agincourt sub-district, South Africa, 2007.

Age group	Stunting	Underweight	Wasting
1-4	17.5	10.0	6.6
5-9	4.5	6.4	5.7
10-14	6.6	6.7	
15-17	6.2	7.8	

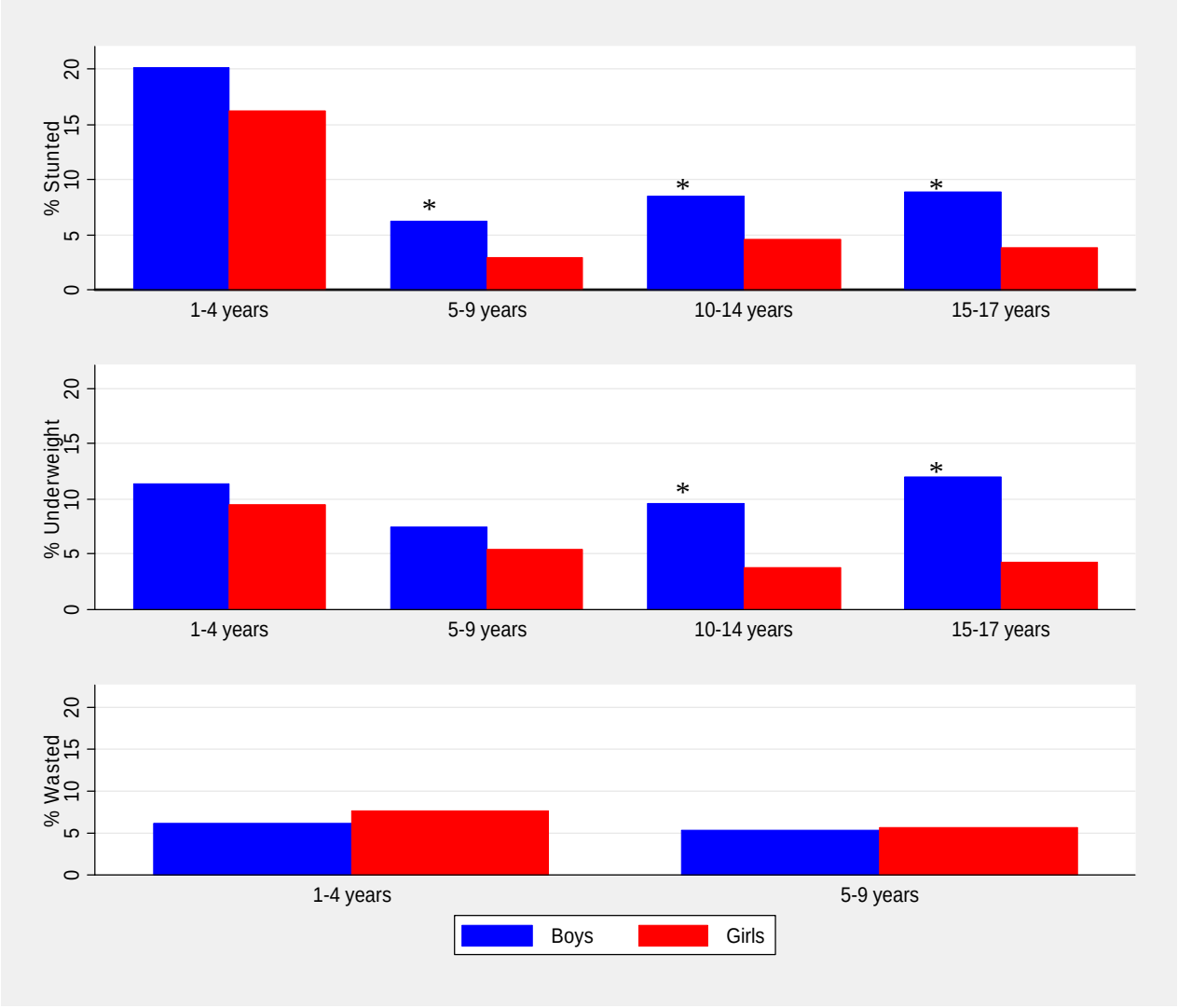

Figure 10: Prevalence of stunting and underweight for children aged 1-17 years and wasting for children aged 1-9 years by sex and age category, Agincourt sub-district, South Africa, 2007

(Significant difference by sex: *p-value <0.05)

4.2.2 Overweight and obesity

BMI and the prevalence of overweight and obesity, determined using BMI (70, 71), are presented in Paper I, Figures 3, & 4 and in Table 7, and in Figures 11, 12 & 13 below.

4.2.2.1 BMI

Figure 11 shows BMI by age category and sex for children aged 1-20 years. Mean BMI was 15.7kg/m^2 in children 1-4 years, went down to an average of 15.0 kg/m^2 in children aged 5-9 years, then rose in subsequent age categories, reaching a peak of 21.1 kg/m^2 in adolescents aged 15-20 years. At young ages (1-4 years), boys had significantly higher BMI ($p=0.002$); the BMIs converged in later childhood (5-9 years), then diverged again during adolescence with girls exhibiting significantly higher BMI at 10-14 and 15-20 years ($p<0.001$, respectively).

With regards to sex difference at specific age points, (Figure 12), except at age 2 where boys' BMI was significantly higher ($p<0.001$), there was no statistically significant difference in BMI between girls and boys during childhood until age 9; from 10 years onwards, girls' BMI remained significantly higher than that of boys ($p<0.050$ at each age respectively).

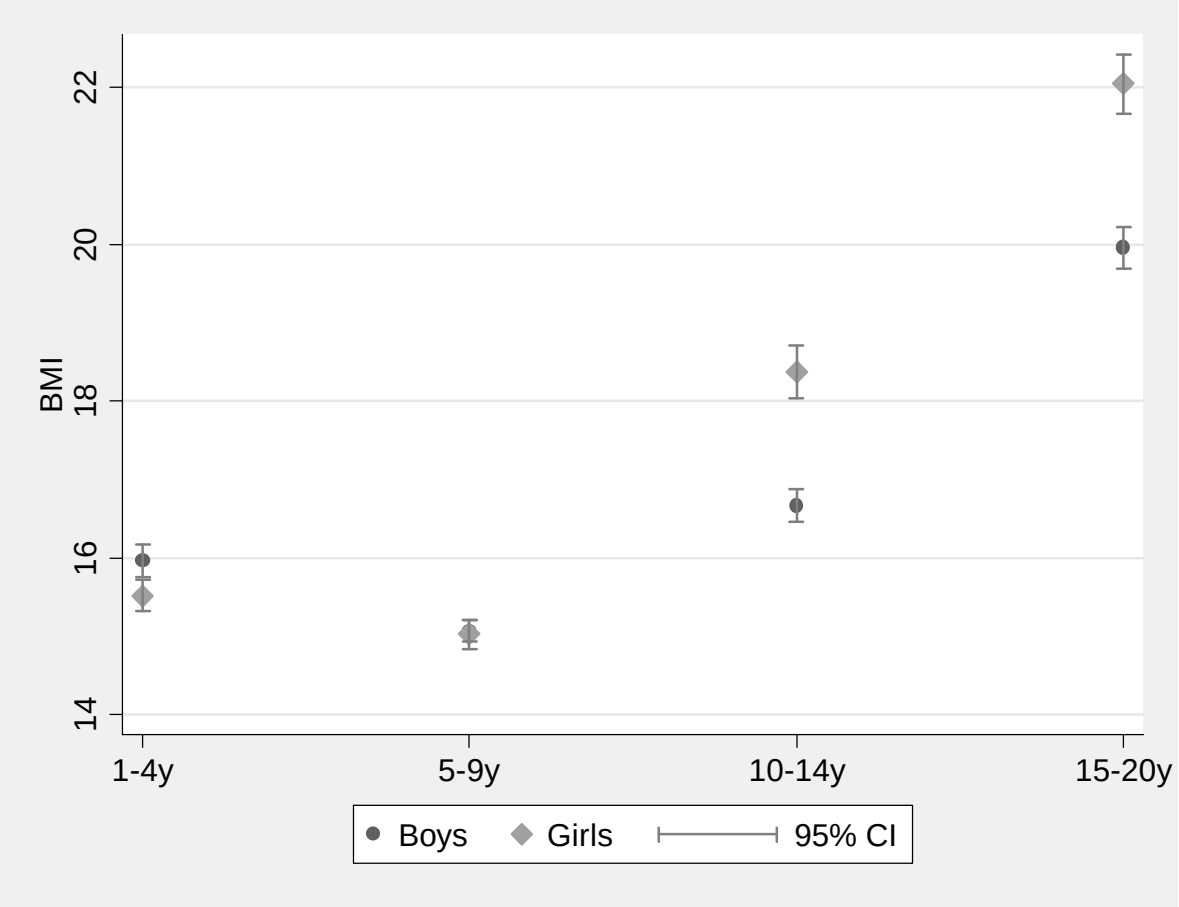

Figure 11: BMI for children aged 1-20 years by age category and sex, Agincourt sub-district, South Africa, 2007

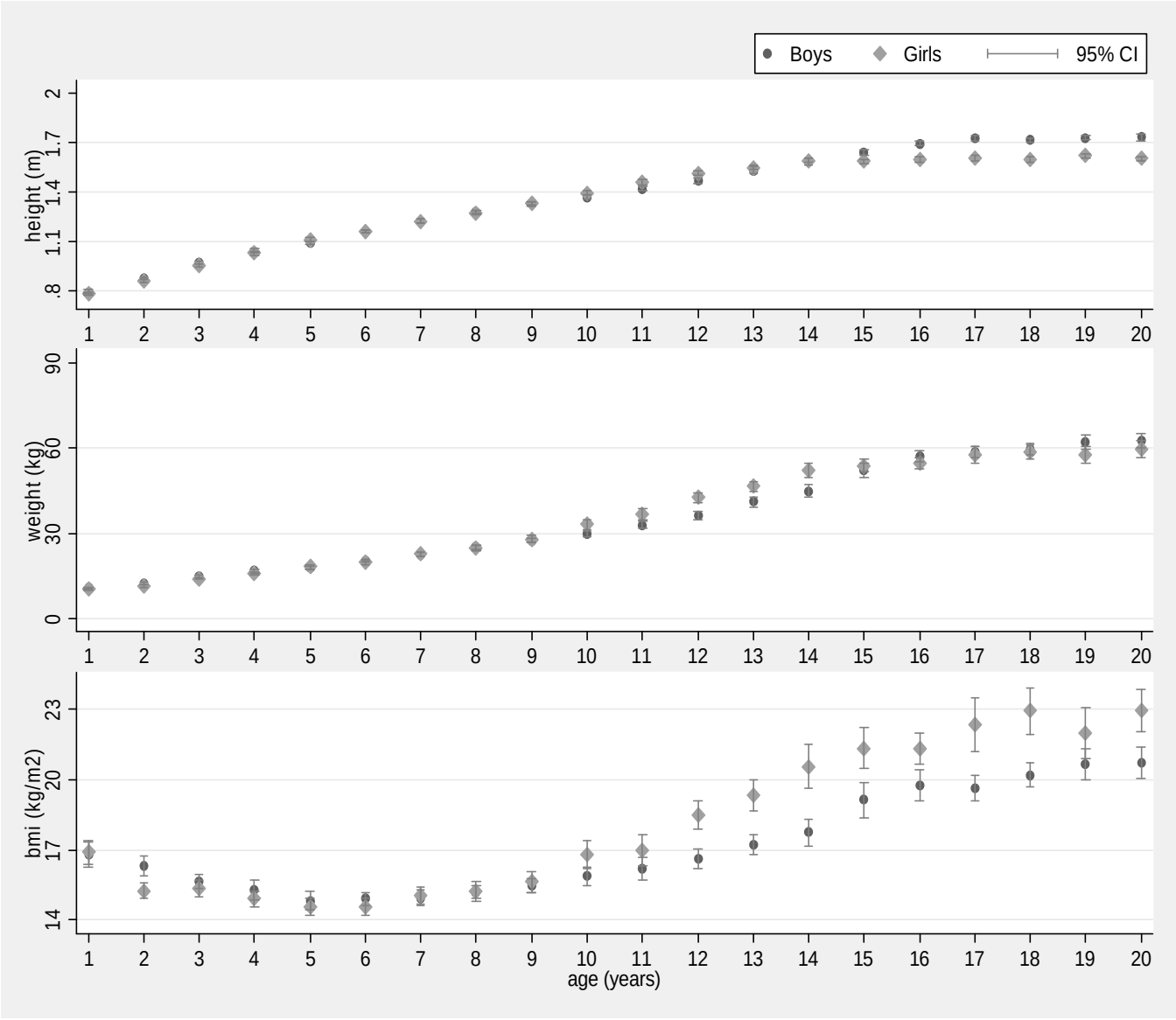

Figure 12: Height, weight and BMI curves for children aged 1-20 years by sex, Agincourt sub-district, South Africa, 2007

4.2.2.2 Overweight

Prevalence of overweight was highest in the age group 15-20 years (8%) (Table 7). It was significantly higher in girls than in boys at age categories 10-14 years and 15-20 years ($p<0.001$, respectively), reaching a peak of 13% in girls in the age-category 15-20 years (Figure 13). With regards to age-specific differences (Paper I, Figure 3), girls had significantly higher prevalence of overweight than boys from age 12-20 years ($p<0.05$, respectively), apart from at age 14 years ($p=0.181$).

With regards to Tanner pubertal staging (Paper 1, Figure 4), overweight remained low in boys across all the tanner stages particularly in stage 5 (0%), while in girls it increased from 7% in stage 1 to 22% in stage 5. It was significantly higher in girls than in boys at Tanner stages 1, 3, 4, 5 ($p<0.05$, respectively).

4.2.2.3 Obesity

Prevalence of obesity was also highest in the age group 15-20 years (4%) (Table 7). It was below 2% in the other age categories. As with overweight, it was significantly higher in girls than in boys in the age categories 10-14 years and 15-20 years ($p=0.020$ and $p=0.004$, respectively), reaching a peak of close to 6% in the age-category 15-20 years (Figure 13). With regards to age-specific differences (Paper I, Figure 3), girls had significantly higher prevalence of obesity than boys at ages 17, 18 and 20 years ($p<0.05$, respectively).

With regards to Tanner pubertal staging (Paper I, Figure 4), it was low in early stages and increased with increasing stages for girls from 0% in stage 1 to 13% in stage 5. It was significantly higher in girls (13%) than boys (0%) at Tanner stage 5 ($p=0.011$).

4.2.2.4 Combined overweight and obesity

The prevalence of combined overweight and obesity was highest amongst adolescents aged 15-20 years at 12% for boys and girls combined (Table 7). The prevalence was moderate in early childhood and low in late childhood, and remained low in adolescent boys. The prevalence was significantly higher in girls than in boys in age categories 10-14 years and 15-20 years ($p<0.001$, respectively). With regards to age-specific differences (Paper I, Figure 3), girls had significantly higher prevalence of combined overweight and obesity than boys at ages 10 and 12-20 ($p<0.05$) but at age 15, the significance was borderline ($p=0.053$). From age 15 onwards, combined overweight

and obesity averaged some 19% in females compared to 4% in males, reaching 25% at 18 years in girls (Paper I, Figure 3). With regards to Tanner stages (Paper I, Figure 4), combined overweight and obesity was lower in the earlier stages of puberty, but increased markedly during the later stages in girls (from 7% at stage 1 to 35% at stage 5); while in boys the prevalence remained low throughout the stages. The prevalence of combined overweight and obesity was significantly different by sex at Tanner stages 3, 4, 5 ($p=0.001$ & $p<0.001$ respectively).

Table 7: Prevalence of overweight, obesity and combined overweight and obesity by age categories for children aged 2-20 years, Agincourt, South Africa, 2007.

Age group	Overweight	Obesity	Overweight + Obesity
2-4	6.9	1.1	8.1
5-9	3.6	0.9	4.5
10-14	5.9	1.6	7.5
15-20	7.9	3.8	11.6

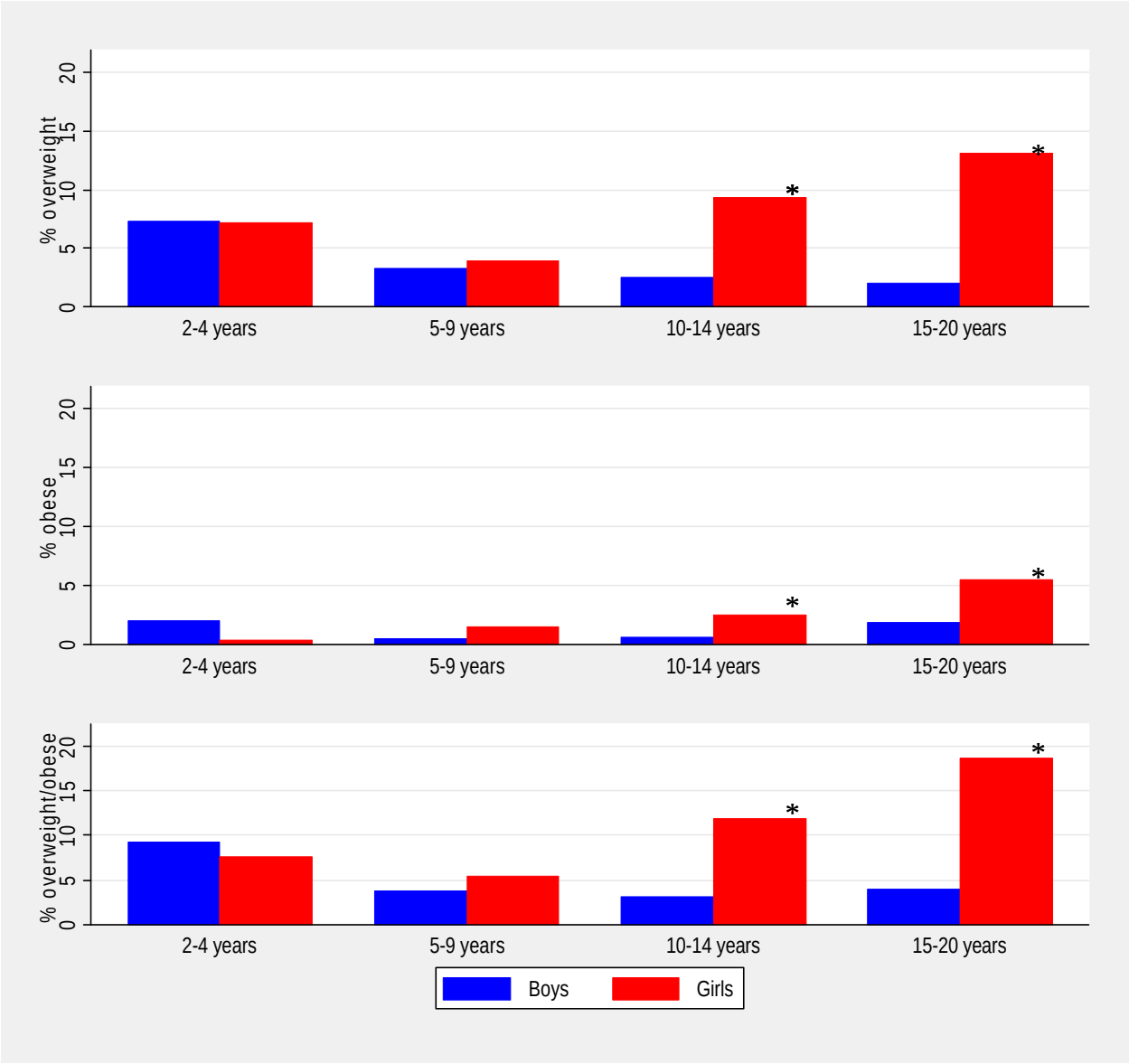

Figure 13: Prevalence of overweight, obesity & combined overweight and obesity for children aged 2-20 years by age category and sex, Agincourt sub-district, South Africa, 2007

(Significant difference by sex: *p-value <0.05)

4.2.3 Risk for metabolic disease

Risk for metabolic disease, measured among adolescents in Tanner stages 3-5 and defined by central obesity using waist circumference and waist-to-height cut-offs (73, 239, 240), is presented by sex and pubertal stage in Paper I, Figure 5.

About 10% of adolescents were potentially at risk for metabolic disease using the waist circumference cut-offs; a significantly higher proportion of girls (16%) than of boys (1%) ($p<0.001$). Similarly, using the waist-to-height cut-offs, 10% of the adolescents were potentially at risk; a significantly higher proportion of girls (15%) than of boys (3%) ($p<0.001$). The prevalence of risk using the different cut-offs was high in girls, almost non-existent in boys, and increasing with increasing pubertal stage in girls (5% in girls at Tanner stage 3 using the waist circumference cut-offs, increasing to 35% at tanner stage 5). There were significant differences by sex across all the Tanner stages using the two cut-offs ($p<0.001$). No boys were at risk of metabolic disease in Tanner stage 5 using the two cut-offs, however, there were fewer boys (n=45) who had attained this stage compared to girls (n=139). (Paper I, Figure 5).

4.3 Adolescent obesity and risk for metabolic disease

This section presents child, maternal, household and community level factors associated with overweight/obesity and risk for metabolic disease (central obesity) among adolescents aged 10-20 years. The analysis involves 1848 participants: 903 (49.6%) boys and 945 (50.5%) girls. Results of this section are mainly presented in Paper IV. Distribution of overweight/obesity and risk for metabolic disease in the study population by explanatory factors is shown (Paper IV, Table 1). Missing values for each variable were allocated an independent category in the regression models to maintain all participants in the analysis. The variables affected include: mother's age (9%), mother's nationality (9%), mother's education (21%), household head education (11%), child's relationship to household head (<1%), food security (4%) and socio-economic status (2%). Test for collinearity among the variables included in the multivariate analysis was done; there was no significant collinearity. Additionally, interaction was tested between various variables significant at univariate level; no significant interactions were found. A brief overview of frequency of consumption of various food items (chicken, fish, red meat, eggs, maize, rice, potatoes, bread, green vegetables and wild foods) by food security status and socio-economic status in the

households of adolescents aged 10-20 years is presented (Paper IV, Table 2). About one in five of the households reported food insecurity (did not have enough to eat in the last one month or one year). Food (in)security status was significantly associated with socio-economic status ($p<0.001$): 27%, 16% and 13% of food insecure households were in the most poor, middle and least poor category respectively. Food secure households consumed most food items significantly more frequently than the food insecure households ($p<0.05$, respectively), other than vegetables, wild foods and maize. Food insecure households consumed vegetables ($p=0.005$) and wild foods ($p=0.002$) more often, while there was no difference in the consumption of maize ($P=0.451$). Similarly, least poor households consumed the various food items significantly more frequently ($p<0.001$, respectively), other than fish, maize, vegetables and wild foods. Most poor households consumed fish ($p=0.001$) and vegetables ($p<0.001$) more often than households in the other socio-economic status categories. Though maize was consumed by almost all households on a daily basis, most poor households consumed it more often ($p<0.001$).

4.3.1 Determinants of adolescent obesity

4.3.1.1 Predictors of BMI

All the child level factors examined (age, sex and pubertal development status) emerged as significant predictors of BMI. Other significant predictors were food security and socio-economic status at the household level. After controlling for other covariates, child's age was positively associated with BMI; for every increase in one year, BMI increased by 0.5 kg/m^2 ($p<0.001$). Girls had close to 2 kg/m^2 higher BMI than boys ($p<0.001$). Pubertal adolescents had 1 kg/m^2 higher BMI than pre-pubertal adolescents ($p<0.001$). Adolescents in food insecure households had 0.4 kg/m^2 lower BMI than those in food secure households ($p=0.040$). Adolescents from the middle socio-economic status households had 0.5 kg/m^2 higher BMI ($p=0.017$), while those from least poor

households had 0.8 kg/m^2 higher BMI ($p<0.001$) than those in most poor households. (Paper IV, Table 3)

4.3.1.2 Predictors of overweight and obesity

Significant predictors of overweight and obesity include age and sex at the child level; and highest education level of the household head and socio-economic status and at the household level. Child's age was positively associated with the odds of combined overweight/obesity. For every increase in one year, the odds of combined overweight and obesity increased by 10% ($p=0.030$). Girls had a 5-fold higher odds of being overweight or obese than boys ($p<0.001$). Adolescents with household heads with education below secondary certificate had 0.6 times lower odds of being overweight/obese compared to those whose household heads had no formal education ($p=0.018$). Those from the highest socio-economic stratum had almost double the odds of being overweight/obese compared to those in the lowest stratum ($p=0.004$). (Paper IV, Table 3)

4.3.2 Determinants of risk for metabolic disease

4.3.2.1 Predictors of waist circumference

All the child level factors examined (age, sex and pubertal development status) were significant predictors of waist circumference. Other significant predictors included food security and socio-economic status at the household level. For every increase in one year of age, waist circumference increased by 1.4cm ($p<0.001$). Girls had 1.6cm wider waist circumference than boys ($p<0.001$). Pubertal adolescents had 3.0cm wider circumference than pre-pubertal adolescents ($p<0.001$). Adolescents in food insecure households had a 1.0cm narrower waist circumference ($p=0.020$), and those from least poor households had a 1.0cm wider waist circumference ($p=0.013$) compared to those in food secure households. Adolescents from the least poor households had almost two-fold

odds of being overweight/obese compared to those in the most poor households (p=0.004).(Paper IV, Table 4)

4.3.2.2 Predictors of central obesity

Significant predictors of central obesity include age and sex at child level; and education level of household head and food security at household level. The odds of central obesity increased by 30% with every increase in one year of age (p<0.001).Girls had a 21-fold odds of having central obesity compared to boys (p<0.001). Adolescents with household head with education lower than secondary certificate had 0.6 times lower odds of having central obesity compared to those with household heads with no formal education (p=0.027). Adolescents in food insecure households had 0.3 times lower odds of having central obesity compared to those in food secure households (p=0.002). (Paper IV, Table 4)

4.3.3 Summary of determinants

Significant predictors of weight status and risk for metabolic disease were similar and include child's age, sex and pubertal development status at the child level; and household head's highest education level, food security and socio-economic status at the household level. Maternal level and community level factors (area of residence) were not significant predictors.

4.4 Child undernutrition in the context of HIV

This section presents HIV prevalence among children aged 1-4 years, patterns of malnutrition by HIV status of the child, acceptability of paediatric HIV testing and effect of HIV status disclosure on caregiving and nutritional status. Determinants of undernutrition, with HIV as a key explanatory factor, are presented. The analysis involves 671 children aged 1-4 years in 2007: 338 (50.4%) boys and 333 (49.6%) girls. These findings are found in papers II and III.

4.4.1 HIV and childhood undernutrition

4.4.1.1 Community acceptability of HIV test and HIV prevalence

Of the 671 children aged 1-4 years, 640 consented to testing, a 95% response rate. All but two caregivers of children who were tested asked for the HIV test results: one did not want to know the result and the other one could not await the result due to other commitments.

Of the 671 children aged 1-4 years, 612 were HIV negative, 28 HIV positive, while 31 were not tested (no consent for the test). Hence HIV prevalence was 4.4% (95% CI: 2.79 to 5.97) in this age group; 3.1% (95% CI: 1.20 to 5.03) in boys and 5.6% (95% CI: 3.10 to 8.20) in girls.

4.4.1.2 Patterns of nutritional status by HIV status

The mean height- and weight-for-age and weight-for-height z-scores were all significantly lower in HIV positive children compared to HIV negative children ($p=0.002$, $p=0.001$ and $p=0.047$, respectively) (Paper II, Table 1). The magnitude of the prevalence of undernutrition was higher in HIV positve children compared to HIV negative; HIV positive children were approximately one and half times more stunted (29% Vs 18%), underweight (14% Vs 10%) and wasted (11% Vs 7%) compared to HIV negative children. However, the differences did not reach statistical significance ($p>0.05$, respectively) (Paper II, Figure 1).

4.4.1.3 Impact of HIV status on nutritional outcomes at community level

The difference in nutritional outcomes between the total sample of children aged 1-4 years (i.e. including HIV positive children) and the HIV free sample (i.e. excluding HIV positive children) was not significant (Table 8). Prevalence of stunting, underweight and wasting for total population was the same in magnitude as that of HIV free population, so no tests for difference of the proportions were done.

Table 8: Nutritional status for total sample of children aged 1-4 years and their HIV-free counterparts, Agincourt sub-district, 2007

	Total Population Mean (SD)	HIV Free Sample Mean (SD)	P-Value
HAZ	-0.96 (1.18)	-0.95 (1.20)	0.813
WAZ	-0.54 (1.17)	-0.52 (1.16)	0.807
WHZ	-0.05 (1.35)	-0.04 (1.34)	0.891

4.4.1.4 Caregiving experiences and nutritional status after child's status disclosure

This sub-section draws mainly from the results of the follow-up study conducted in 2008, presented in Paper III. Findings are mainly from interviews with caregivers of HIV positive children, supplemented by group discussions with Home-based Care Groups and a Community Advisory Group (CAG) also conducted in 2008. Further, nutritional status is reported from anthropometric measurements of HIV positive and negative children in 2008. All the 35 children aged 1-5 years determined HIV negative in 2007 participated in the 2008 follow-up study. Among the HIV positive children, two had died prior to the 2008 follow-up study, one was away with the mother for an extended period, and one caregiver refused to participate. Thus 31 caregivers of HIV positive children participated in the follow-up study; all were women, 24 (77%) biological mothers, four (13%) grandmothers and three (10%) other relatives. Twenty four caregivers (77%) knew the child's HIV status, three of whom already knew this before the 2007 HIV test. Two mothers and 5 non-maternal caregivers did not know the child's status. For the two mothers, this was because results were not disclosed to them for reasons earlier stated. The 5 non-maternal caregivers had taken on caregiving after the 2007 study mainly due to death of the mother before disclosure (four

mothers died within the one year follow-up). Among those who knew the HIV status, 22 participated in the in-depth interviews while two refused to participate. One interview was erroneously not recorded. The narratives presented are therefore based on 21 in-depth interviews, of which 19 were with mothers, one with a grandmother and one with a sister of the child. Information from open-ended questions in the questionnaires was used to supplement information from in-depth interviews. Data from HIV negative children is only reported in the nutritional status sub-section.

Perceptions, attitudes and behaviour regarding knowing a child's HIV status

Knowing a child's HIV status

Caregivers felt positively about knowing the child's HIV status. Most caregivers (19, 90%) indicated that they had accepted the test results. While slightly more than half (12) reported accepting the results immediately, others reported initial reactions such as anxiety, fear, disbelief, surprise, worry and denial when they learnt of the child's status but most of these had accepted the results by the time of the follow-up study as the following respondent expresses:

> "It shocked me a little bit; I mean I was worried at that time, but really the time we are living in, it is not only my child who is sick. (…) I have accepted it. (…). My heart was doubting, saying "it is not true… they lied". Now I accept everything. If you go to church you have to accept everything; to live is in the hands of God. I have gone to many places seeking this matter" (Mother, 34 years).

Counselling by health professionals helped the women to cope: "I was frightened, then I went for counselling (at the health facility), then I was fine and free. I thought that the child would die; but after counselling I have accepted it; I don't fear anything" (mother, 33 years). Spiritual beliefs - "it is what God has wanted it to be" (mother, 25 years), fate or lack of alternatives - "if I don't accept

it, there is nothing I can do" (mother, 39 years),social support after disclosure to others, and self-consolation were also important.

Knowledge of child's HIV status could lead to favour or discrimination against the child, but extreme reactions were uncommon. Caregivers felt that children should be treated the same regardless of their HIV status "they are all the same I take care of them equally" (Mother, 50 years), and there was generally no indication of differential treatment in terms of general care, feeding and health seeking. However, caregivers occasionally gave priority to a child with HIV particularly with regards to health care, assuming the child had less resistance to infection than other children:

> "If there is not enough food in the household or all children are sick, she is the first priority because there is a difference with this HIV and usually there is illness" (Sister, 26).

Sometimes it was informed by need to protect other children:

> "If (the illness) for the other children is not serious we are very busy (seeking care) for that one (who is HIV positive) so that she may not infect other children" (Mother, 29 years).

Disclosure of child's HIV results

Though disclosure of the test results to other people was expressed as a difficult task, most caregivers 13 (62%) had disclosed the child's HIV status to at least one person; the rest had not disclosed. Most people only felt comfortable disclosing to their close relatives. The first point of disclosure was the child's father (24%), followed by the child's grandparents (24%), particularly maternal grandmother or the child's siblings (14%) where the child's father was not part of the family. Only two (10%) had disclosed to other relatives (their own siblings) and only one (5%) to non-relatives. Accepting and feeling comfortable with the test results was key in disclosure of the results to other people. Counselling at the health facility also influenced disclosure of child's status.

Despite many people feeling comfortable disclosing to close family members, expressions like "I never told anyone" or "I don't want to talk about it" were not uncommon, repeated by almost half of the respondents (48%). However, out of these, two said they had disclosed to their first line family members. Thus "anyone" referred to other people outside the family. Some people did not trust other people enough to disclose the results to them, while some did not see the benefit of disclosing the results. Fear of stigma, discrimination and scandal for the child and for themselves were barriers to disclosure, particularly outside their close circle of relatives. Often people feared that others' reactions would have adverse impact on the child. In one case, there was also fear of divorce, and in an another, fear of extermination of the child by community members. The following respondent highlights some of the fears expressed:

> "I don't like telling other people because if you tell a person he/she will tell their friends. (…) Some can say, "this child is ill; do not play with her, she has a certain illness". You know children will keep on telling each other that this child is ill, it will go all over the place. So to tell a person, it is difficult for me. It will end up hurting and I will finally be having high blood (pressure). I don't know these people; I didn't grow up with them. I am speaking to you because you will give me advice. Other people will say, "she was a prostitute". (…) Here at home I only tell my son that they said that this child is sick with this disease. (…) Someone may kill your child, because you said she has a particular illness. The time when I grew up it was said that our father had TB, because the neighbours knew about it, they finally killed him and they said he was killed by TB. If they didn't tell one or two people that he has TB, he would be alive" (Mother, 42 years).

Disclosure of results to other people, particularly to potential caregivers particularly in case of death of the mother is important with regards to care for the child. However, some mothers hid this important knowledge to other potential caregivers. In fact, only two non-mother caregivers of HIV positive children knew the child's HIV status. The discussion with the Community Advisory Group

indicated that children's HIV status is hardly known in the community. They indicated that one of the reasons for this is that a child's status would be linked to the mother's status. Because there is still lack of understanding about HIV mothers want to keep it secret:

> "Once she says the child is positive, it will be linked to her. And she doesn't want her status to be known. It is difficult to disclose, we still have challenges of making people understand the issue of HIV." (…) Our people have a problem; some of them when they are sick they say that they are bewitched, some of them say they have disease which is caused by not practicing traditional rituals after the funeral perfectly" (Group Discussion with Community Advisory Group).

Fears and aspirations for the future

Almost all caregivers expressed positive aspirations for the future of the child in terms of their health, and ability to grow and live like other children like "the child is fine; I have nothing to be fearful of. I wish her to grow like her brothers and sisters" (Mother, 31 years); go to school; and grow up to assume adult responsibilities like "I don't want anything other than to see the child growing and being a woman" (Grandmother, 57 years).

A salient aspiration was that a cure for HIV would be found so the child would be cured. Thirteen respondents (62%) expressed no particular fear currently or with regards to the child's future and expressions similar to the one below were not uncommon:

> "Now I don't have any fear, I am not concerned, one can't run away from illness, I must accept everything that comes" (Mother, 42 years)

Others feared poor health, compromised when the caregiver was financially constrained, and death:

> "It has affected me because I don't know for how long the child would live, and this illness is difficult for him because sometimes you can even think that he is going to die. Actually

there is no peace" (Mother, 32 years)

While others feared infection of the caregiver or other children from body fluids:

"what scared me is that I have to bath her and sometimes she has sores and I'm using bare hands, so I am worried that I will get infected too" (Mother, 25 years).

Caregiving to an HIV positive child: perceived usefulness of knowing status

Caregivers emphasised that knowing the child's HIV status enhanced their competency in caregiving as it led to helpful advice from health professionals and other people such as relatives. Caregivers expressed faith in advice from health professionals "If they tell you at the hospital that it (something) is good, it is good" (Mother, 42 years). Most (95%) of the respondents said that knowing the child's status was helpful in one way or another. This perceived usefulness was in terms of heightened hygiene, protecting other children from infection, heightened health seeking including for ART and child feeding.

Hygiene and general health care-seeking

Although several respondents maintained that their children led "normal" lives like other children, and a few indicated that the children rarely got sick, most caregivers reported frequent flu, sores and other illnesses, although such illness was not debilitating: "She is so active and plays very well; even when she's got flu or diarrhoea, she copes very well with it" (grandmother, 57 years). Sometimes these illnesses spread to other children in the household; "My children live with sores; maybe it is because of HIV or it may be because they (sores) like them; I can't differentiate it" (Mother, 33 years). The poor health status of the children indicates need for adequate attention to hygiene and health care-seeking, and caregivers noted that knowing the child's status awakened their knowledge in this area:

"Your visit opened our minds; we should not think that it is flu only while it is not (…)

I found happiness this year. Last year I knew, I opened my mind, I took steps. (…) If you had not come to tell us I would have been lost (…) (what I have learnt is that) if she plays she must play where it is safe, if she coughs she must not infect other children, and if she gets injured she should not touch another child. (…) I cover her sores, so that she doesn't infect other children" (Mother, 29 years).

Anti-retroviral treatment seeking

Though most children were not on anti-retroviral treatment, knowing the child's HIV status stimulated the caregivers to seek anti-retroviral treatment for the child. Three children were on ART at the time of the study. Eight other women had sought ART but the children had not been placed on medication for medical reasons and other barriers: according to health professionals, the child's immune system was still sufficiently strong; they were awaiting test results before a decision could be made; the child was too young for ART; or the caregiver lacked transport money to collect the drugs. Two of the caregivers whose children were on ART reported that the child's health had consequently improved; one was still waiting to assess the effects of treatment.

Child feeding

Knowing their child's status opened the caregivers to advice on feeding practices as the following respondents expressed:

"I now know the illness that she has; what those who know it call it, they opened my eyes. You who are educated, you opened our eyes (…) I know that I must buy meat and rice. In the past I only knew that they have to eat African herbs. I didn't know that even bread and butter helps. I didn't know that spinach helps; we were just eating" (Mother, 42 years).

"There are things we were not giving the child though the child was supposed to get. They (health professionals) told us about fruits, vegetables, exercise" (Sister, 26 years).

Challenges to caregiving

Caregivers of HIV positive children faced barriers in caring for the children including financial barriers, poor access to health services, and compromised physical ability to provide care due to their own poor health. Caregivers often linked financial limitations to not having a job or being able to work themselves, having no husband, the father of the child being unemployed or reluctant or unable to support them, and to inadequacy of the government child support grant. These barriers limited their effective care, including their ability to feed the child well:

> "There are foods which I wish that my child could eat, foods that they told us at the hospital; foods that make blood flow; like beetroot, carrots, potatoes, spinach and fruits. (...) I can't get the food because I am not working, I don't have a husband, you get food if you have money, everything they (health professionals) mentioned needs money; if you don't have money, how are you going to get it? (…) the little money (referring to child support grant) I get for them is not enough it doesn't meet our needs. I only afford maize meal" (mother, 36 years).

Barriers to health care included shortages of drugs, e.g. antibiotics for opportunistic infections and limited access to ARVs: "we can't collect the treatment (ARVs) because of money" (mother, 30 years). ARVs are provided by only one health facility in the community, a public-private health centre distant from many of the villages. Although ARVs are free, cost of transport to the facility and long queues limit treatment seeking. ARVs are also provided for free by the district hospitals, but they are even further away (the nearest is about 25km). The limitations mentioned by the caregivers were echoed by Home-based Care Groups:

> "The agency where they get ARVs is too far and they don't have money to go there. It would be good if they (government) could move the agency, or have another one in the nearest community or village" (Group discussion with Eco Plan Home-based Care Group).

> "There is a waiting list at the agency where they receive ARVs and you find that people die while waiting for those ARVs" (Group discussion with Xanthia Home-based Care Group).

Additionally, some caregivers feared that health professionals, particularly at the nearby clinics, would not maintain confidentiality about their child's HIV status, and others felt that health care providers had bad attitudes and did not respect them. These barriers led caregivers to shy off or choose other options, such as attending the more distant hospital:

> "When we go to the hospital they help us, but at the clinic they have a bad attitude; I went there and I found that they were treating me in a bad manner, I didn't go back there. The way they talk, it doesn't make me feel free. Most times when I want to visit the clinic I go to the mobile clinic. If you take them (children) to the clinic with flu, they say 'these people have one illness; we have a shortage of medicine here at our clinic and they'll use up the drugs for other people.' Most of the time there is no medicine at the clinic and at the end of the month, I buy medicines and headache pills (from a private outlet) and put them away safely" (mother, 42 years).

There were also some gaps in information about care for HIV positive children, particularly concerning feeding; "I have changed nothing … I still give her the same food because I don't know what kind of food I should give her" (mother, 34 years). Additionally, caregivers expressed gaps in knowledge with regards to health care particularly antiretroviral therapy, at the end of the interviews several respondents asked about ARVs and indicated an interest in further information. A few caregivers also indicated misconceptions about HIV in children; two caregivers believed that the illness will be cured; that the child's blood is dirty and since the child is still young will be cleaned with time probably through good feeding or traditional medicine and this gave them false hope and aspirations in caring for the child (the two preferred to have their children on traditional medicine rather than ARVs):

"I know that if I can give her this food with energy, at the end this blood will be clean; she is still young she will be cured. The blood will be clean and get back where it was in the past. It is easy for a young child to be cured, it is the same as a child who injured an arm or leg; she gets cured if she is still young, it is not the same with an old person. (…) I see that they say AIDS tablets are not curing HIV, they make it quieten, if she abandoned them, it (the virus) will wake up, I think it is better to leave them. I give her traditional medicine, it is killing (the virus), (…) we were syringing her (with the traditional medicine) so that the dirt that is inside comes out. (…) Pills (ARVs) are better for me because I am old. (…). When I syringe (her with traditional medicine), the virus comes out and goes" (Mother, 42 years)

Support networks for caregivers of HIV positive children

Various support networks are available to caregivers, including informal social support from relatives and friends, and community-based and government initiatives. Support acquired included emotional support or empathy, instrumental support such as counselling or advice and encouragement to seek care, practical support such as with house work, and material support such as with food and money including acquiring food supplements from health facilities. A few caregivers borrowed money and food from neighbours, while many depended on the government's child support grant (ZAR240 per month i.e. approx USD30 per child <15 years). Respondents felt that this grant was inadequate, while the care dependency grant, which could be accessed by caregivers of HIV positive children, and disability grant, which could be accessed by HIV positve mothers, can only be accessed once the CD4 count goes below 200/microL. Caregivers pleaded for more financial and material support, such as food, from the government. This was supported by home-based carers:

"They (government) need to give people who are HIV positive a grant as most of them are very poor and they can't afford a balanced diet. The government needs to revise the policy

that allows HIV positive people to receive support grant (disability grant) only when their CD4 count is below 200 because many of them die before receiving the grant" (Group discussion with Eco Plan Home Based Care Group).

Support from other people often followed disclosure of the child's status. However, in instances when the caregivers were not comfortable disclosing, expressions like "I don't get any support because it is my secret" (Mother, 25 years) were not uncommon.

Home-based Care Groups may be instrumental in care of HIV positive children as they are close to people. Some six Home-based Care Groups operate in the different villages. Discussions were held with five of these groups concerning their support activities for HIV positive people in the community and the challenges they face.

Activities to support HIV positive people include:

- Practical support such as with cooking and feeding the sick, and cleaning
- Instrumental such as counselling, advice and encouragement to seek care for example antiretroviral therapy, and to seek social support such as government grant
- Nursing care such as cleaning critically ill people and giving drugs; and
- Material support including bringing them drugs from health facilities such as for TB

However, home-based carers are usually referred to HIV positive people from the health facilities. This means that it is usually only those HIV positive people known to the health facilities who get this support. Several caregivers were reluctant to seek or accept support from these community-operated Home-based Care Groups due to perceived lack of confidentiality. This reluctance was confirmed by the home based carers themselves.

The home based carers pointed out several limitations they face in undertaking their duties, which need to be addressed for them to be effective in their work. These include:

- Rejection by people living with HIV or their relatives for reasons including that carers don't have anything concrete to offer like food. They indicate they are tired of hearing about HIV:

  "We are locked out by people; some people do not want to see us at their homes; when we go there, they lock us out of their houses because we do not have anything for them; we do not have any food to take to them. " (Group discussion with Lillidale Home-based Care Group);

- Lack of supplies for self protection

  "We do not have protective gear; no gloves, no aprons, no nose masks; our health is at risk because when we visit the sick people, there are times when we find that the person has passed stools and the place s/he is staying has a bad smell and we are expected to bath that person without protection" (Group discussion with Xanthia Home-based Care Group); and

Lack of their own subsistence as they work on a voluntary basis.

While support groups for people living with HIV exist in the community, and may also be instrumental in building resilience, only one caregiver pointed out joining a support group.

Probable impact of knowing child's HIV status on health and nutritional status

Perceived change in health and nutritional status

Probably the heightened health-seeking led to improved health status and growth of the child as most caregivers felt the child's health and growth had improved between the time of the HIV test and the follow-up study. However, a few indicated some deterioration, while a few others indicated no change.

Expressions similar to the one below were common:

> "The child's growth has changed, this year she is better, not very ill, it is not the same with last year. Even food, she eats very well and is growing taller" (Mother, 27 years)

Nutritional status one year after HIV test with disclosure

Weight of both HIV positive and negative children in the 2008 follow-up study was taken. Comparisons were made with paired samples of HIV positive children and HIV negative children, aged 1-4 years in 2007 who participated in both 2007 survey and the follow-up study in 2008. Thus, non-participants and deceased children in 2008 were excluded. Against expectation, the mean weight-for-age z-scores for HIV positive children had improved from -1.3 (95% CI: -1.9 to -0.7) in 2007 to -0.7 (95% CI: -1.2 to -0.2) in 2008 while for HIV negative children had marginally improved from -0.4 (95% CI: -0.8 to -0.0) in 2007 to -0.2 (95% CI: -0.5 to 0.1) in 2008. The improvement in z-scores for the HIV positive children was significant (p=0.046) while that of HIV negative children was not significant (p=0.108). The difference in mean z-scores by HIV status in 2008 was not significant (p=0.129), yet for the same sample, it was significant in 2007 (p=0.019).

4.4.2 Determinants of childhood undernutrition

This sub-section presents determinants of undernutrition in children aged 1-4 years (n=671), with HIV as the key predictor examined. Distribution of explanatory factors in the study population by HIV status is presented in Paper II, Table 1. In the multivariate regression analysis, missing values for each variable were allocated an independent category to maintain all participants in the analysis. The variables affected include birth weight (22%), household head education (10%), mother's education (7%), food security (6%) social economic status (2.5%), and mother's age, mother's nationality and household head relationship to child (<2% respectively). Test for collinearity among the variables included in the multivariate analysis was done; there was no significant collinearity. Additionally, interaction was tested between various variables significant at univariate level; no

significant interactions were found. Results of multivariate regression analysis are shown in Paper II, Tables 2, 3 and 4.

4.4.2.1 Height-for-Age Z-scores

At multivariate analysis level, significant determinants of HAZ were HIV status, age and birth weight of the child; and mother's age (all $p<0.050$). HIV positive children had significantly lower HAZ than HIV negative children ($p=0.001$); age was positively associated with HAZ ($p<0.001$); low birth weight was negatively associated with HAZ ($p<0.001$); while children of younger mother aged 15-24 years had significantly lower HAZ than of mothers aged 25-34 years ($p=0.005$) (Paper II, Table 2).

4.4.2.2 Weight for Age Z-scores

Controlling for other covariates, significant determinants of WAZ were HIV status and birth weight of the child; mother's age; and household head's age (all $p<0.050$). HIV positive children had lower WAZ than their HIV negative counterparts ($p=0.001$); low birth weight was negatively associated with WAZ ($p<0.001$); children of mother's aged 15-24 years had significantly lower WAZ than of mothers aged 25-34 years ($p=0.011$); while children of household heads younger than 35 years had lower z-scores compared to those of household heads in the age-category 35-49 years ($p=0.047$) (Paper II, Table 3).

4.4.2.3 Weight for Height Z-scores

Controlling for other covariates, significant determinants of WHZ were only at child level and included child's age and birth weight. Both age and low birth weight were negatively associated with WHZ ($p=0.001$ & $p<0.001$, respectively). (Paper II, Table 4)

4.4.2.4 Stunting

At multivariate level, key determinants of stunting included child's age and area of residence. Age was negatively associated with stunting ($p<0.001$); while children living in villages mainly inhabited by people of Mozambican origin had more than a two-fold higher odds of being stunted ($p=0.024$). Association of stunting with mother's age was borderline ($p=0.051$), with children born to mothers younger than 25 years having a 1.6 higher odds of being stunted than children born to older mothers aged 35-49 years. Though there was an association with HIV, with HIV positive children having slightly more than a two-fold higher odds of being stunted, the association was not significant ($p=0.075$) (Paper II, Table 2).

4.4.2.5 Underweight

Only low birth weight was a significant predictor of underweight after controlling for other covariates: children with low birth weight had a three-fold higher odds of being underweight than other children ($p=0.002$). HIV positive children had 1.5 times higher odds of being underweight, but the association was not significant ($p=0.512$) (Paper II, Table 3).

4.4.2.6 Wasting

No factor was significantly associated with wasting at multivariate analysis. Though the odds of being wasted were close to two-fold if the child was HIV positive, the association was not significant ($p=0.333$) (Paper II, Table 4).

4.4.2.7 Summary of determinants of childhood undernutrition

Significant predictors include child's HIV status, child's age, birth weight, maternal age, age of household head, and area of residence. HIV status was strongly associated with z-scores but its association with stunting, underweight and wasting was not significant at the 5% level of significance.

5.0 Discussion

This thesis explores child and adolescent growth patterns in a high HIV prevalent rural setting in a middle income country undergoing rapid economic and social transition following democracy. The study describes patterns of nutritional status in children and adolescents aged 1-20 years by age and sex, and among adolescents aged 9-20 years by pubertal stage; patterns of nutritional status by HIV status for children under five years of age; and factors associated with malnutrition at individual/child, maternal, household and community levels (as portrayed in the adapted model Figure 1). In recognition of the role of HIV on nutritional status and eventual mortality of infected children due to malnutrition, (26, 27) this study explores the acceptability and usefulness of paediatric HIV testing with disclosure and referral for standard health care, on caregiving and nutritional outcomes.

This section discusses the results in relation to national and international findings. It is organised into three thematic areas: patterns of malnutrition; adolescent obesity and risk for metabolic disease; child undernutrition in the context of HIV (Table 1).

5.1 Patterns of malnutrition

Key Findings

- Substantial levels of undernutrition, particularly stunting, under age two; and stunting and underweight among adolescent boys
- Marked prevalence of overweight and obesity, particularly among adolescent girls
- Elevated risk for metabolic disease among adolescent girls

A substantial prevalence of undernutrition, particularly stunting in early childhood is documented in this study. The levels of undernutrition in young children in this rural community correspond with

earlier findings in South Africa (Table 2), while a higher prevalence of undernutrition in rural rather than in urban areas has been documented. (33-36) As in other South African studies, (33-36) stunting was most prevalent in this study: 18% in children aged 1-4 years. This indicates that stunting has persisted post-Apartheid. The prevalence is comparable to findings documented in national surveys up to 15 years ago, among children up to nine years of age. (33, 35, 36) (Table 2) Interestingly, a national survey of children under five years of age in 2003 documented a substantial level of stunting (27%), suggesting that the prevalence of stunting may have increased post-Apartheid. (34) The rates of stunting are comparable to those observed in low-income countries such as Zimbabwe, Senegal and Togo, (76, 211) despite South Africa being a middle-income country. In children under five years in this study, the prevalence of underweight (10%) is within the range (9-12%) documented in national surveys since the end of Apartheid, and the prevalence of wasting (7%) is slightly higher than the range (3-5%). (33-36) Despite the substantial prevalence of stunting children younger than five years, the study documents a low prevalence of stunting in those older than five years, particularly in those aged 5-9 years. Part of the explanation for the much lower prevalence of stunting in the 5-9 year olds could be the use of different standards/references to generate the height-for-age z-scores; the 2006 WHO standards for children aged less than five years and the 1977 NCHS/WHO reference for those from five years on. Use of the 1977 NCHS/WHO reference results in a lower number of children being classified as stunted compared to the 2006 WHO standards (241)

The study also highlighted a higher prevalence of undernutrition amongst adolescent boys compared to girls, confirming findings in other national South African studies. (153) The distribution of undernutrition by gender in LMICs is mixed: some studies report male children as more vulnerable to undernutrition, (99, 100) other studies, particularly in Asia, indicate higher vulnerability among girls, (101) and yet others find no gender effects on nutritional status. (102) Evidence on younger children indicates disproportionate male undernutrition in households with

lower socio-economic status; in more well-off households, the sex difference disappears. (105) The differential prevalence of undernutrition by sex among adolescents in our study is likely to be due to delay in the pubertal growth spurt in boys as compared to the reference group. This occurs where undernutrition is prevalent. (242) Other studies in South Africa have documented delayed pubertal development for children in rural areas as compared to their urban counterparts. (243) Other factors may also contribute to these differences: even after stratifying by pubertal stage, boys in Tanner stages 2 and 3 still showed significantly higher levels of underweight compared to girls in the same stages, indicating that gender-based differences in nutritional status during adolescence requires further investigation.

The prevalence of undernutrition in this study and others conducted since the end of Apartheid (33-36) indicates little progress in addressing the problem of undernutrition in South African children. This is despite rapid economic and social transition, and new policies and programmes to address the problem. (208) Household food insecurity persists as a major problem in South Africa: despite being a middle-income country and regarded as food secure at a national level, some 35% of households are considered food insecure. (29) Household food insecurity dates back to the Apartheid era, when land was sub-divided into small plots in former homelands, plots too small to support subsistence farming. The Agincourt sub-district, typical of former homeland areas, is located in a geographically inhospitable area with a limited food production base. Hence people have to rely heavily on purchased food which – in an area with low purchasing power – may result in food insecurity and consequent undernutrition. Poor nutritional outcomes may not only be associated with the quantity of food but also the quality: food variety and dietary diversity associated with nutritional status in children, are limited in South Africa. (244)

HIV/AIDS, highly prevalent in South Africa (32, 223) and in the study area (37, 223), may play a major role in the persistence of undernutrition. The high prevalence of HIV among women of child

bearing age (37) indicates that many households are affected by HIV and its socioeconomic impacts. HIV/AIDS has a major impact on food security as it undermines the ability of households to provide for their basic needs. (30) HIV/AIDS has been implicated in increased adult mortality in the study area. (222, 245) Adult mortality, particularly that of a male wage-earner, has been shown to affect household food security, with households resorting to wild foods as a coping strategy. (246) While HIV/AIDS accounts for close to 50% mortality of women in the child-bearing age in the study area, (245) death of a mother has been associated with a fourfold increase in the odds of child undernutrition. (108)

Concurrent with the levels of undernutrition, this study also documents substantial levels of overweight and obesity among adolescents in the same community. Similar findings have been documented elsewhere in South Africa. (33, 35, 46) (Table 3) The levels documented in this rural area, though marked, are lower than those recorded in national surveys. (33, 35, 46) The South African Youth Risk Behaviour Survey 2002, documented a prevalence of combined overweight and obesity of 21% among adolescents in grades 8-11 (approx 13-19 years) nationally: 7% in boys and 25% in girls. (46) Our study documented a prevalence of about 10% in this age group: 4% in boys and 16% in girls. The prevalence of overweight and obesity has been higher in urban areas than rural areas in past studies. (35) Though the South African Youth Risk Behaviour Survey 2002 did not report separate results for urban and rural areas, levels were higher in the more urbanised and industrialised provinces. (46, 207) The lower levels of overweight and obesity reported in our study suggest possible sub-populations where overweight/obesity in South Africa may be concentrated. Further context-specific research on overweight and obesity among South African children and adolescents is needed. Results not shown indicate that concurrence of both stunting and overweight/obesity was rare in our study sample; only 19 children (<1%) experienced the phenomenon, most of whom (14) were children aged less than five years. This phenomenon was therefore not explored further.

As in other South African studies, our study reported higher prevalences of overweight and obesity among adolescent girls, and almost non-existent levels in adolescent boys. (46, 47, 153) This is consistent with several studies in other LMICs. (247) Few studies, however, have also documented higher prevalences in boys. (248) The prevalence of overweight and obesity in South African girls compares to that found in several upper-middle- and higher-income countries, while that of boys is lower. (153)

In line with overweight/obesity, this study also documented a noteworthy prevalence of risk for metabolic disease using central obesity among adolescent girls. The risk increased with sexual maturation, reaching a peak during the final pubertal stage. This is of great public health concern, as risk for paediatric metabolic syndrome is becoming increasingly important in the LMICs. (11) Additionally, risk components for the metabolic syndrome have been tracked from childhood to adulthood in several studies, (187) indicating need for early interventions to prevent transfer of risks to adulthood.

The phenomenon of the double burden of malnutrition documented in this study is increasingly common in other LMICs undergoing nutrition transition. (1, 2) Several factors shed light on this phenomenon. Studies have indicated that exposure to undernutrition early in life leads to short stature later in life, particularly in women; while short stature in later life has been associated with higher risk of obesity and metabolic diseases. (249, 250)

Literature on developmental programming describes how early life insults including nutritional deprivation during the foetal period and early childhood, provoke permanent adaptations that may lead to obesity, metabolic syndrome and type 2 diabetes during later life. (21, 138, 141, 142, 251, 252) This may partly explain the co-occurrence in our study of substantial levels of undernutrition in early childhood, particularly stunting at age one year, with overweight, and obesity, and risk for

metabolic disease during adolescence. Further, most of the adolescents, particularly those aged 15-20 years, were born during or shortly after the Apartheid era when nutritional deprivation due to political restrictions of the South African black population may have been worse. Developmental programming of children in deprived households may have occurred, while socio-political changes since 1994 may have increased access to energy-dense food. A mismatch between foetal and infant programming and the later environment may account for the later development of obesity and metabolic disease risk. (21, 138, 141, 142, 251, 252).

Change of food cultures and lifestyle may also have a major role to play. Extensive labour migration documented in the study area, particularly circular migration to larger towns, (198, 220, 232) facilitates the transfer and introduction of urban practices to rural settings with consequent change in diet and lifestyle. Women's participation in the labour force, increasingly reported in the study area, (219, 253) impacts on food supply and diet and has been associated with increased intake of processed foods prepared outside the home. (51) Studies elsewhere in South Africa have reported decreased intake of staple foods, including maize meal with urbanisation, and increased intake of energy-dense foods including added fats and oils and animal-derived foods. (41)

Similar findings have been documented in other LMICs undergoing nutrition transition. (1) The study area is characterised by low local food production and thus overreliance on purchased food, often energy-dense processed foods, may be inevitable. Discussion with a Community Advisory Group in the study area (data not presented) indicated that one of the possible factors leading to paediatric obesity is consumption of junk food, sold in the community particularly near schools (Group Discussion, Community Advisory Group, June 2008).

A few confilicting findings not-withstanding, (170) physical inactivity and sedentary lifestyles are associated with child overweight and obesity. (52, 160, 169) National electrification in South Africa

in the last few years, with consequent increase in televisions at home, may have reduced physical activity. Studies in South Africa have reported decreased physical activity among adolescents (151, 207) Increased TV viewing by children/adolescents may also be associated with increased consumption of unhealthy foods seen in TV advertisements. (84) Length of TV viewing by children has been associated with higher consumption of fast foods and other high energy dense foods, and lowered intake of fruits and vegetables. (173) The Community Advisory Group indicated that the the marked overweight/obesity in children and adolescents was mainly due to westernisation: households, especially those with working parents, tend to employ house maids who do most household chores. Thus children spend a lot of time viewing television and do little active work. (Group discussion with Agincourt Community Advisory Group, June 2008). Contribution of these factors to the patterns of obesity require further investigation.

5.2 Adolescents obesity and risk for metabolic disease

Key Findings

- Risk factors for adolescent obesity and risk for metabolic disease are at individual/child and household levels
- Child level factors include: age, sex and pubertal development
- Household level factors include: household head's highest education level, food security and socio-economic status

This study has identified risk factors for adolescent obesity and risk for metabolic disease at child and household levels. About 5% of the study participants were classified as underweight according to International Obesity Task Force criteria, 6% boys and 4% girls. However, most of those underweight were in the age group of 10 to 11 years of age and in pubertal stages 1 and 2, indicating that they were still growing. Exclusion of these children only marginally altered results, thus they were maintained in the final analysis. At the individual level, child's age, sex and pubertal

development emerged as key predictors. Consistent with other studies, obesity and risk for metabolic disease in the study participants increased with increase in age and were positively associated with pubertal development. (47, 151) This may reflect effect of factors such as increased sedentary behaviour and decreased physical activity with age and pubertal onset related to subsequent physical, social and emotional changes. (152, 164) A test of correlation indicated a significant correlation between age and pubertal development (though there was no collinearity). This may indicate some attenuation of effect of either of these variables by the effect of the other.

The higher risk of obesity and risk for metabolic disease in girls is akin to findings in many studies in other LMICs (247) and in South Africa in particular. (46, 47, 153) However, in a few settings, higher prevalence in boys has been documented. (248) Several factors may explain the sex difference in our study. Biologically, energy needs differ for boys and girls and also in relation to rate of growth. Further, timing of maturation differs by sex. (254) Behavioral factors are also important in explaining the sex differences. Boys are generally more physically active, participate more in sports and are physically fitter compared to girls, especially during adolescence (162-164); the differences have been documented in South African youth too. (151, 207) A dicussion with the Community Advisory Group (data not presented) confirmed these gender differences. The group indicated that girls tend to be less physically active than boys; while boys play soccer after school, girls have little options for physical activity and often visit taverns in the afternoon (Group discussion with Agincourt Community Advisory Group, June 2008).

Concerns about body image particularly among adolescent girls may lead to problematic eating behaviours such as irregular meal patterns which may result in increased weight gain. (255, 256) A higher level of problematic eating behaviours has been documented amongst female than among male youths in South Africa(257). On the other hand, as in many African countries, studies in South Africa have indicated that in rural areas and in low socio-economic status settings, heavier

bodies among females are preferred even during adolescence (258, 259). This may therefore result in obesity among adolescent girls. Though more investigation is needed to establish perceptions on body image among adolescents in the study area, given findings elsewhere (257-259) there may be a need for interventions addressing body image during adolescence, particularly among girls.

At the household level, a household head's highest education level, food security and socio-economic status were key predictors of obesity and risk for metabolic disease among adolescents. While the education level of the mother did not matter, education level of the household head was significantly associated with obesity. Education may affect nutritional status through knowledge of proper diet and the harmful effects of overnutrition. Education level may also affect income levels, hence it may affect diet and sedentary lifestyle. In this study, a small amount of education was protective across the various measures of weight status and central obesity. However, the education level that would substantially affect socio-economic status in the study community (completed secondary and tertiary education) was not significantly associated, though it tended towards a positive association with obesity. There seems, therefore, to be a mixed effect: while on the one hand education is protective, it also leads to higher BMI and central obesity. This mixed effect may explain why there was no association at higher levels of education. Additionally, a test for correlation indicated significant correlation between household head's education level and socio-economic status (though no significant collinearity); this may indicate attenuation of effect of either of these variables caused by the effect of the other.

Available literature on the association between food security and child/adolescent obesity is generally conflicting. (260-262) In high-income countries, food insecurity is often associated with child/adolescent overweight/obesity, (260) despite some studies indicating otherwise. (261, 262) Similarly in LMICs, though limited literature exists, some studies have found a positive association between food insecurity and overweight/obesity, while in other studies the association is negative.

(260) Given a low food production base in the study area, food security may relate strongly to ability to afford purchased food - in a society undergoing nutrition transition, this may generally mean energy-dense processed foods.

The relationship between socio-economic status and obesity varies across different countries depending on economic development. (263) The direct relationship found in this study is in keeping with other studies in LMICs. (247, 263) However, in high-income countries, many studies have indicated higher risk among lower-income communities, (263) as the poor may opt for cheaper energy-dense processed foods. (264) However, even in high-income countries such as the United States, the reverse association between socio-economic status and obesity is said to be weakening over time. (265) Further, the association is population specific; for example, a direct relationship is found among African-American children and adolescents, and a reverse association among White children in the US. (265) There are also population-specific variations observed in some other settings. (266) Though South Africa is classified as a middle-income country, there is high intra-country inequality with regards to income distribution, with high levels of poverty in some regions. The area where this study was conducted is low-income, located in a province with one of the highest poverty rates in South Africa. (195) Pathways through which socio-economic status is associated with obesity include through income, education and occupation, resulting in behaviours which influence the balance between energy intake, expenditure and metabolism. (267) In this study we only tested the education pathway for which data were available. It would be important to investigate the other two pathways in future studies in the study setting.

Socio-economic status is associated with sedentary lifestyle and lower physical activity; the rich are more likely to afford sedentary lifestyles including television viewing and less strenuous activities. Results not shown indicate that while slightly below 50% of those in the most poor category owned a television, almost all of those in the least poor category did (96%). Again, while only 7% of those

in the most poor category owned a car, which is likely to reduce time spent walking, 35% in the least poor category owned one.. Additionally, the richer households, whose members are more likely to work outside of the home, are more likely to employ house maids, resulting in decreased physical activity among children and adolescents (Group Discussion with Agincourt Community Advisory Group, June 2008).

Socio-economic status may dictate purchase of food items; while the rich can afford to purchase processed foods, the poorest cannot afford them and may therefore rely on their limited farm products and wild foods. It is no surprise then that households in the most poor category consumed vegetables, wild foods and the main staple (maize) more often than those in the least poor category. Similar observation was made with regards to fish, some types of which (e.g. hake) are cheaper than other meat in South Africa. Those in the least poor category and in food-secure households more often consumed higher fat animal products such as red meat and chicken. Consumption of animal source foods and energy dense foods has been associated with overweight/obesity in countries undergoing nutrition transition. (48) It is unfortunate that in low-income settings, those who are able to afford energy dense processed foods are also more likely to afford sedentary lifestyles. This leads to an imbalance between energy consumption and expenditure and leads to overweight/obesity. A test for correlation indicated socio-economic status and food security variables were significantly associated (though not significantly collinear). This may indicate attenuation of the effect of either of these variables caused by the effect of the other.

5.3 Child undernutrition in the context of HIV

Key Findings

- HIV infection plays a significant role in nutritional status of children
- Paediatric HIV testing with disclosure to caregiver has potential to ameliorate the negative role of HIV on nutritional status
- Other covariates of childhood undernutrition include a child's birth weight and age; maternal age; age of the household head; and area of residence within community.

5.3.1 HIV and childhood undernutrition

This study documents a fairly low HIV prevalence among children aged 1-4 years, that is comparable to 2005 South African national estimates among children aged 2-4 years (5%) (223), despite high HIV prevalence among women of child-bearing age. (37) This may be due to efforts to prevent transmission of HIV from mother to child in South Africa. PMTCT programs have been scaled up in South Africa in the last few years and some milestones have been achieved, for example antenatal HIV testing and uptake of nevirapine for infected mothers. (206) On the other hand, the apparently low prevalence may also indicate the death of HIV infected children at an earlier age as about half of children infected with HIV die before their second birthday without ART. (268) This is particularly plausible given the negligible proportion of caregivers who knew their children's HIV status before the HIV testing in this study, hence had limited chances of seeking ART promptly. The prevalence of HIV is however important both for individual wellbeing of the children and for public health purposes. HIV infection influences nutritional outcomes of infected children at an individual level, (27) while malnutrition in HIV infected children leads to higher mortality. (26) HIV in children has been associated with marked demographic impacts in South Africa. Dorrington et al. (2006) estimated that 44% of mortality among children aged 0-14

years was due to HIV, despite only 2% of this age group being infected. (201) Additionally, increases in child mortality due to HIV/AIDS and HIV-related diseases such as TB in the study area have been recorded since the 1990s. (45, 213)

This study documents poorer nutritional outcomes, particularly z-scores among HIV positive children, as compared to their HIV negative counterparts. The role of HIV was important even after controlling for other covariates of malnutrition. Growth failure has been associated with HIV elsewhere in sub-Saharan Africa (25, 26) and in South Africa in particular. (269) In settings with unhygienic environments, often in rural settings, infections in children, particularly diarrhoea, are important causes of undernutrition in young children. (17) Recurrent illness such as diarrhoea in HIV positive children due to lowered immunity, may have a major role in their nutritional outcomes. Diarrhoea, a common opportunistic infection in HIV positive children, is particularly important in growth retardation of infected children. (119) Diarrhoea has been documented in up to 90% of HIV-positive children in Africa, with chronic diarrhoea six times more likely to develop in HIV-infected children than in their non-infected counterparts. (270) While HIV infected children require 50-100% more nutrients than non-infected children, (271) lower food intake in HIV infected children, due to anorexia or co-morbid conditions, may lead to nutrient deprivation and undernutrition. In the study area, a major part of malnutrition-related deaths in children are due to HIV. (45, 213)

This study indicates the potential for community paediatric HIV testing in alleviating the role of HIV on nutritional status of infected children. The study indicates a high acceptance rate for paediatric HIV testing and high acceptance of the results. Knowledge of HIV status was perceived as valuable since it enhanced a caregiver's competency in providing care to the child. The high level of acceptance of the HIV test and the high positive attitudes towards knowing the child's HIV status were unexpected, given that stigma persists in South Africa. (204) Additionally, a child's

positive HIV status usually indicates maternal infection. Studies have demonstrated negative anticipated or experienced consequences of perinatal testing of mothers including anxiety, health care discrimination, social discrimination, and marital violence and abandonment. (272, 273) Such fears may have implications for the ability of the caregiver (usually the mother) to accept the test or the test results of the child. Acceptance of test results is important as it is closely related to caregiving and adherence to advice from health professionals, (274) while denial of results hinders health care-seeking and social support. (275) Positive attitudes may reflect the healing effects of time in the presence of continuous counselling and other support. (276, 277)

Studies on the child rearing practices of caregivers of HIV positive children indicate that attitudes of caregivers are mixed between regarding caregiving as an honour and a burden. (278) Conceptualisation of HIV as "social and physical death" may hinder constructive reactions to knowledge of a child's HIV status. (275) Caregiving may be influenced by social stigmatisation, financial limitations and emotional strain. (274, 278) Positive aspirations for the child by the caregiver may have positive implications on the care given to the child. The finding on high positive aspirations in this study differs from a Ugandan study, indicating that some mothers would not care for an HIV positive child, as the child would 'die anyway'. (274) The positive aspirations documented in this study may need further scrutiny as some studies elsewhere have documented higher levels of wishful thinking with regards to the future of the child among caregivers of HIV positive children than of HIV negative children. (278)

This study documented an unexpectedly significant improvement in nutritional status of HIV positive children within one year of follow-up. It would be expected that the nutritional status of HIV positive children would worsen with time, as the HIV disease progresses over time. The improvement may be associated with heightened care following disclosure of HIV status and referral for standard health care and improved hygiene practices for HIV positive children.

Additionally, all children who were malnourished were also referred for nutritional advice and support. Heightened health care and hygiene practices are likely to lead to less infections, while infections could lead to poorer nutritional outcomes. Studies have indicated improvement in z-scores in children following introduction of ART, (279) however, only three children in our study were on ART and though none of them were undernourished, the number is too small for reaching any definitive conclusion. This study is not able to clearly establish the factors related to this improvement and calls for further investigations, involving a larger sample and closer follow-up.

Barriers to caregiving for HIV positive children reported in this study are important, and mirror experiences of caregivers of HIV positive children and of people living with HIV elsewhere. (278, 280) Financial restrictions were a major limitation. The government's child support grant was the most important source of income, although most respondents regarded it as inadequate. Since most mothers of HIV positive children are also likely to be infected, their opportunities for formal employment are limited. The financial and physical limitations indicate a need for creative and effective income generating strategies as evidenced in other settings, (281) particularly for mothers of HIV positive children who may also be infected. Further, the disability grant offered by the South African government to physically and mentally disabled people aged 18-65 years provides good support to people living with HIV/AIDS. (282) However, recipients only qualify if they are too sick to work, and may lose it if their health improves following antiretroviral treatment. (280, 283) In line with suggestions made in this study, the policy may need revision to allow access before disability sets in, particularly for mothers who are HIV positive and are also taking care of HIV infected children. The care dependency grant targeted at children with disability less than 18 years, while useful in caring for HIV positive children, can also only be accessed when children reach the later disabling stages of the disease. (284)

Gaps in knowledge with regards to caring for an HIV positive child particularly with regards to ART were evident in this study. This may indicate differential health-seeking or acquisition of information regarding care of HIV positive children, even though all caregivers were referred for counselling and advice at the health facilities. Despite documented importance of ART in the growth of infected children, (285) this study demonstrates poor utilisation due to both supply and demand issues. On the demand side, there is limited access due to financial barriers (cost of transport to the single service providing ART in the community), and lack of adequate information on ART. On the supply side, there are limited facilities close to people where ART can be initiated, hence the need for step-down facilities for monitoring and treatment.

Many caregivers obtained support from others in caregiving, particularly from relatives. However, there was reluctance to disclose to people outside of close family circles. Again, few mentioned accessing special support and services geared specifically towards people living with AIDS, such as food supplements or being in support groups. This may relate to the stigma associated with HIV, hindering caregivers from disclosing the child's status outside the family and inhibiting access to special external support. This reluctance may also relate to attitudes anticipated or experienced by respondents from health professionals. Interventions, including community campaigns to create awareness, and education and motivation to improve the practice of health care professionals, are therefore needed. Further, despite the perceived utility of knowing a child's HIV status, there was also reluctance to transfer this knowledge to the next-line caregiver. This was evident where the child's mother had died, as most non-maternal caregivers were unaware of the child's status. This indicates the need for re-emphasis of disclosure at least to potential next-line caregivers.

Support groups may play a major role in providing continuous counselling and mentorship to caregivers of infected children, important in building resilience. (277) They may function as a conduit for continuous peer education on caregiving and filling in information gaps. However, few

reported joining support groups, suggesting a gap in awareness of the value, or of the stigma associated with seeking HIV-related support and services. Additionally, there was little mention of support from non-governmental organisations such as Home-based Care Groups located in the community. This may be because support often followed disclosure, and caregivers mentioned fear or lack of confidentiality as inhibiting disclosure to home-based carers. These organisations could play a major role in reducing barriers to care, as they would bring services closer to people. There is a need for awareness of their role in the community, and education of home-based carers on confidentiality, to enhance client confidence. Further, Home-based Care Groups unanimously pointed out limitations to their effective work in the community, including lack of basic supplies and remuneration that need to be addressed.

Despite HIV being an independent, modifiable risk factor for undernutrition, it is important to discuss the public health implications of including HIV positive children in nutritional assessments at the community level. This study documents an insignificant impact of HIV status on the nutritional status of children in the community overall, as the proportion of infected children was small. Therefore, given the technicalities of HIV testing at community level, this study indicates no need for HIV screening of children during community nutritional assessments in similar settings. Nevertheless, HIV screening in communities is indicated for other reasons, particularly given its impact on child mortality. (201)

5.3.2 Determinants of childhood undernutrition

Risk factors for undernutrition in children aged 1-4 years, other than HIV, included factors at individual/child, maternal, household and community levels. These include a child's birth weight and age; maternal age; household level: age of household head and area of residence within the community. This study documented a noteworthy prevalence of low birth weight found nationally, (34) and in some sub-populations elsewhere in South Africa. (286) Though further investigations

are needed to establish the causes of low birth weight in this setting, factors including maternal health status and household food insecurity leading to maternal undernourishment may be important. Household food insecurity, prevalent in South Africa and in the study area, may have an adverse impact on pregnant mothers. Maternal undernourishment during pregnancy may result in foetal growth retardation as insufficient nutrient intake or absorption by the mother leads to deprived foetal growth. (287) Birth weight was lower in HIV positive children compared to their negative counterparts, as also found in other studies in sub-Saharan Africa. (121) Maternal HIV infection which leads to higher rates of maternal opportunistic infections, has been particularly associated with foetal growth retardation leading to smaller size and low birth weight. (120) Child age was differentially related to nutritional status. With regards to height-for-age z-scores and stunting, indicators for chronic undernutrition, older children had better outcomes, while with regards to weight-for-height z-scores, older children had poorer outcomes. The height-for-age z-scores and higher stunting in younger children may be associated with low birth weight, followed by catch-up growth in the older years. The poorer outcomes related to weight-for-height z-scores in older children may be associated with weaning practices. (288)

At the maternal level, maternal age was a significant determinant. Maternal age has been documented in other studies in the developing world as an important risk factor for childhood undernutrition. (104) The increased risk of undernutrition in children of mothers aged less than 25 years may be associated with the mothers being too young to give adequate care to their children. It may also relate to maternal constraints during pregnancy related to maternal size, hence potential for low birth weight which is further associated with the nutritional status of the child. (289) The higher risk of poor nutritional outcomes in children with very young mothers indicates need for community and school-based education, to reduce early pregnancies and to devise post-school training and job opportunities particularly for girls. At the household level, only age of the household head emerged as a predictor of nutritional outcomes. The pathway through which age of

the household head may influence nutritional outcomes of the child could be through income and food security.

At the community level, area of residence being a proxy for various factors including environmental risks, availability of services and shared cultures, emerged as a significant predictor of nutritional outcomes. Children living in villages mainly inhabited by people of Mozambican origin had poorer nutritional outcomes. These villages served as refugee settlements during and after the civil war in Mozambique from the early to mid-1980s. Consequently, well over 90% of people living in these villages are of Mozambican origin, whereas they constitute about 30% of inhabitants over the study site as a whole. Though the situation is changing, people in these villages have lived with limited legal recognition without being fully integrated into South African society. The villages have poor dwellings and infrastructure and are worse-off than predominantly South African villages with respect to basic services including water, sanitation, electricity and health facilities. (217, 290) Other researchers in the study area have also found poorer health outcomes in children living in former Mozambican households. (291) While this study showed that being born to a mother of Mozambican origin does not disadvantage the child with regards to nutritional outcomes, previous work documented significantly higher mortality in children born to Mozambican mothers as compared to those born to South African mothers. (292) Community interventions to improve living conditions could contribute to better health and nutritional outcomes in children. These interventions may include improvement in provision of basic services such as water and sanitation facilities, and improved infrastructure. Additionally, improved social integration of people of Mozambican origin through speedy provision of identity documents may improve the nutritional status of their children through prompt access to government social grants such as child support grants.

5.4 Linkage between findings and conceptual framework

This study has confirmed linkages between factors affecting nutritional status among children as portrayed in the conceptual framework for this thesis (Figure 1). It has documented different categories of factors affecting a child's nutitional status at individual, household (including maternal) and community levels. The study identified biological and environmental factors affecting children's nutritional status. Behavioural factors were not examined and need further research. Further, this study has documented marked levels of overweight/obesity, further confirming the influence of a nutrition transition on nutitional status in this rural community.

5.5 Study limitations

Llimitations of this study can be categorised into three broad domains: sampling, non-response, and measurement.

5.5.1 Sampling

The sample for the 2007 growth survey was drawn from the existing Agincourt Health and Socio-demographic Surveillance System. The time lag between data collection for the Agincourt HDSS sampling frame and data collection for the growth survey meant that infants under one year of age were not included. This limitation may have lowered the proportion of children with HIV infection reported in our study, and masked the extent of poor nutritional outcomes in HIV positive children, as the most vulnerable children may have died by their first birthday. (268) Further, the results on the association between undernutrition and HIV status should be interpreted with caution, given the small proportion of HIV positive children as the small size may bias the strength of the associations. Power calcualtion was done and it was not adequate to detect significant differences between the HIV positive and HIV negative sub-samples. It is therefore possible that though the study indicates no statistically significant effect of HIV infection on the nutritional status (stunting, underweight

and wasting), the effect, which was generally big could have been significant if the proportion of HIV positive children was higher. It is recommended that this effect be investgated in future studies with larger samples.

5.5.2 Non-response bias

There was higher non-participation among older adolescents, mostly because they were away from the study area during the study period. As documented in other studies including in the study area, (293) this age group is highly mobile, particularly for higher education and labour reasons. This non-participation may indicate over-representation of the overall study sample by younger children. Additionally, children in boarding schools may have different dietary and physical activity patterns compared to children in day schools, and this could have introduced a bias in the results, particularly with regards to obesity.

Some explanatory variables had missing values. To minimise bias, missing values for each variable were allocated an independent category in the regression models, to maintain all participants in the analysis.

5.5.3 Measurement

One limitatition with regards to measurement relates to the HIV tests employed. We used two rapid tests to detect antibodies. According to WHO recommendations, antibody tests are appropriate for HIV screening in children aged 18 months and above. As maternal antibodies may still be present in younger children, examinations to detect the virus, rather than antibodies, are recommended for children younger than 18 months. (230) However, studies have found that most uninfected HIV-exposed children have lost maternal antibodies by 12 months of age; hence an HIV antibody-positive test at this age may be considered indicative of HIV infection. (230, 294) Further, since only three children under 18 months of age tested HIV positive in our study, the likelihood of

maternal antibodies affecting the results is low. It is also worth noting some strengths of the rapid tests used. We used two concurrent tests; Unigold^{TM} and Determine,^{TM} to enhance accuracy of the results. Only when there was concordance in the two tests was a decision made; there was negligible discordance. The two tests are simple to perform and yield results rapidly. Additionally they both have high sensitivity (100%) and specificity (>99.5%). (295)

The food security tool used was primarily designed as a simple tool to measure trends in household food security in the Agincourt health and socio-demographic surveillance area over time rather than to detail multiple dimensions of food security, which would have been important in this study.

Another limitation of measurement relates to failure to include proximal factors to explain malnutrition, particularly obesity, and additional distal measures. This study did not collect data on food intake and physical activity patterns, which would shed more light on the findings. However, further work focusing on these factors is underway. Data on some important distal measures including occupation of the mother, paternal characteristics such as education status; and household income were not included as data were not available. It would be important to investigate these in future studies. Additionally, child support grant may play an important role in nutritional status of children in this low-resource setting. However, though data on child support grant is collected in the Agincourt HDSS, the available data was generally incomplete and could not be used in this thesis. It would be important to investigate in future studies the role of child support grant in nutritional status for both people of South African origin and of Mozambican origin.

5.6 Strengths of the study

Despite the limitations listed above, this study has key strengths that are worth mentioning. The study makes a worthwhile contribution to the understanding of the nutritional status of children and adolescents in a wide age spectrum of 1-20 years in a rural disadvantaged province of South Africa. The investigation of both undernutrition and overnutrition among children and adolescents in the same community, particularly in rural areas is uncommon in low- to middle-income countries. This thesis therefore adds greatly to the existing knowledge on the double burden of malnutrition in LMICs.

The study was able to establish HIV prevalence among children aged upto five years in a randomly selected sample and use this data in determining association between HIV infection and nutritional status of the children. This is a key strength of the study; technicalities of HIV testing of young children and ethical issues limit evidence on nutritional status and other health outcomes of HIV positive children in randomly selected samples at population level. This study thus makes an important contribution in establishing the wellbeing of HIV positive children in a community setting.

A further strength of this study was in the methods used. The sampling for the study was purely random, using an existing sampling frame, and representative of the study area as the study sample was drawn from the various villages in proportion to the population size of the villages. Triangulating both quantitative and qualitative methods added to the strengths of the study. Qualitative exploration on how HIV testing may have impacted on caregiving for HIV positive children helped to understand some of the quantitative results observed, resulting in a stronger piece of work. Additionally, full participation of the author in the fieldwork ensured quality of data collection and interpretation of the results particularly with regards to the qualitative data.

6.0 Conclusions, Implications and Future Research

6.1 Conclusions and implications

This study set out to explore the profile of malnutrition and risk factors in a high HIV prevalence, rural setting in South Africa. Figure 14 demonstrates the hierarchical organisation of factors influencing malnutrition that were examined in this study, particularly, risk factors for childhood undernutrition, and adolescent obesity and risk for metabolic disease. We found that substantial levels of undernutrition, particularly stunting at an early age, co-exist with marked levels of overweight/obesity, particularly in adolescent girls. In addition, we documented elevated risk for metabolic disease in adolescent girls. HIV emerged as an independent modifiable risk factor for childhood undernutrition, with a potential for community-based paediatric HIV screening in ameliorating the role of HIV on undernutrition. Other covariates of undernutrition include a child's age and birth weight at individual level; maternal age and household head's age at household level; and area of residence as a proxy for community level factors. Determinants of adolescent obesity and risk for metabolic disease were noted at the individual level, including age, sex and pubertal development; and at the household level including household head's highest education level, food security and socio-economic status.

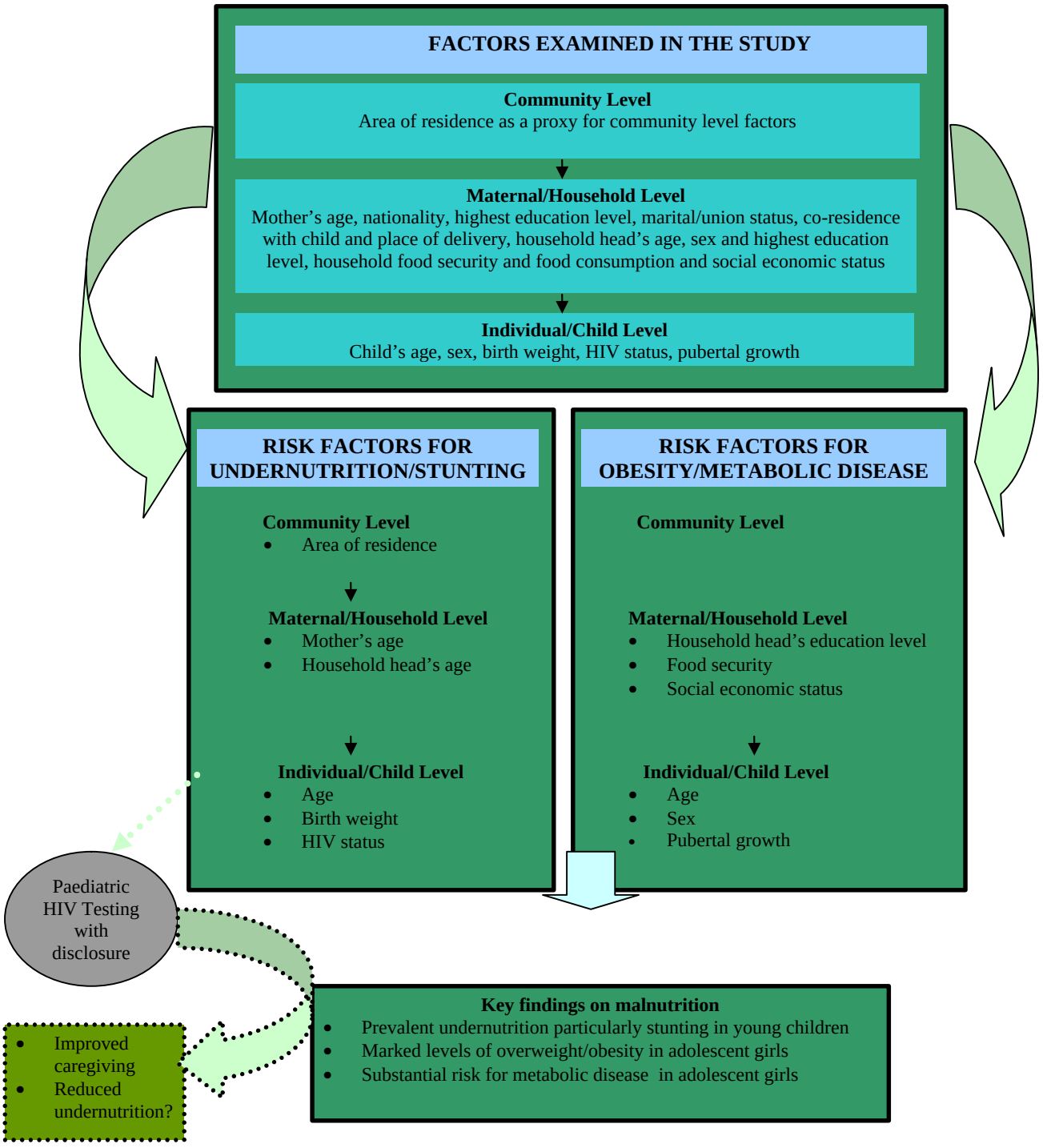

Figure 14: Key study findings, Agincourt sub-district, South Africa, 2007

The level of undernutrition in this community, particularly stunting, at early age is surprising in a country that has transitioned economically into a middle-income country. It may suggest inadequacy or ineffectiveness of interventions that were put in place in the post-Apartheid era as a priority to address food insecurity and malnutrition. It may also indicate the need to emphasise interventions during the perinatal period. The potential role of HIV in the persistence of undernutrition cannot be overemphasised. Its negative effect on nutritional status documented in this study may be the tip of the iceberg; given high HIV prevalence in the area, (37, 200) many more children than those infected are affected by HIV and its impacts.

The levels of overweight and obesity, particularly among adolescent girls, indicate that child growth and nutrition in rural South Africa is clearly shifting along the rural-urban continuum and is tending towards an urban-like profile. It is likely that this profile relates to changes in nutrition and dietary patterns in South Africa as in other LMICs. (1, 2) However, variation in other factors such as infectious disease burden, patterns of physical activity, and social influences need to be investigated. Further, the co-existence of prevalent overweight/obesity with stunting in this community may indicate developmental programming in this community; this would need further investigation.

These findings have implications for public health policy and practice. As obesity and adult short stature are both risk factors for cardiovascur diseases and type 2 diabetes, (12, 296) the combination of early stunting and adolescent obesity may be an explosive combination. The overweight/obesity prevalence in adolescents, particularly girls, may partly contribute to the high levels of overweight/obesity reported in South African adults, particularly women. (34) The high risk for metabolic disease in adolescent girls is of great public health importance as chronic diseases associated with obesity are already contributing markedly to the burden of disease in this community and other parts of South Africa, particularly among adults. (45, 212, 297)

The findings call for evidence-based interventions to alleviate the dual burden of malnutrition. With regards to obesity and metabolic disease risk, the study has identified determinants that may help in pointing out target groups for obesity prevention programs. Gender sensitive programs targeted particularly to adolescent girls, are needed. Although further research is required to clearly establish the proximate causes in this particular community, findings in other settings in South Africa, (151, 207, 257) reinforced by the views of the Community Advisory Group in this study, suggest interventions should address physical inactivity, sedentary behaviour and dietary patterns, particularly among adolescent girls. Recreation facilities in the community, particularly for girls, and physical education programs in schools may play an important role. Additionally, it would be important to consider body image when designing obesity prevention and control programs as studies have shown that people including adolescents, particularly in rural areas and among low soci-economic groups in South Africa prefer heavier figures which may lead to obesity (258, 259).

To address undernutrition, effective maternal interventions such as nutrition education and food programmes, focusing on nutrient-rich foods are recommended to aleviate hunger and improve nutritional aoutcomes. The higher risk of poor nutritional outcomes in children with very young mothers indicates need for community- and school-based education to reduce early pregnancies, and post-school training and job opportunities particularly for girls. Interventions to improve nutritional outcomes of children infected or exposed to HIV may include improving access to and utilisation of PMTCT services, and targeted paediatric HIV screening and support to infected children. Despite the scale-up of PMTCT programs in South Africa in the last few years, (206) access to and utilisation of these services remain a challenge particularly in rural areas, (202, 203) and are in urgent need of improvement. Where PMTCT has failed, early detection of HIV positive children is critical for prompt and appropriate medical management, reduction of morbidity and mortality, and improvement of quality of life. (230, 279) The high level of paediatric HIV test uptake in the study indicates that paediatric HIV testing in children is acceptable in this rural

community; this may be the case in other settings. Further, this study has demonstrated perceived usefulness of paediatric HIV testing with disclosure on caregiving, with consequent improvement in nutritional status. Targeted community-based paediatric HIV screening for exposed children, with appropriate referral and follow-up measures (230) is therefore recommended. Interventions targeted specifically at HIV positive children could include food supplementation (25) and antiretroviral treatment. (279, 285) However, several barriers highlighted in the discussion, including financial and health care access barriers, need to be addressed to reap the best from such an undertaking.

With regards to financial limitations, the respondents indicated high dependancy on child support grant but which was said to be inadequate. The government may need to reconsider the allocations of child support grant. Given the physical limitations of mothers of HIV positive children, who are most likely positive also, creative and effective income generating strategies need to be initiated for them as evidenced in other settings. (281) Additionally, the policy on disability grant may need revision to allow access before disability sets in; particularly to mothers who are HIV positive and are also taking care of HIV infected children. (280, 282, 283) On the same vein, policy restrictions on the care dependency grant may need to be relaxed for HIV positive children so that they access it even before they reach the later disabling stages of the disease. (284) Access limitations (particulalrly to ARVs) were closely linked to financial limitations, hence addressing financial limitatitions may greatly address the problem of access. Additionally, the government should increase the ARV distribution centres through equiping government health facilities (hospitals and health centres) to play this role. Other potential interventions targeted to particularly vulnerable children of young mothers and those from villages predominantly inhabited by people of Mozambican origin, have been highlighted.

In summary, the findings of this study indicate that rural South Africa, like other LMICs, is undergoing a nutrition transition. The findings present a multifaceted policy and programme

challenge that calls for further evidence and research. The study recommends a scaling up of research and programme evaluation in order to better understand the nutritional transition, and to inform effective policy, preventive and intervention strategies to address the double-pronged problem of malnutrition in South Africa and elsewhere in sub-Saharan Africa.

6.2 Further research

This study has described the more distal factors associated with co-existing undernutrition, overweight/obesity and risk for metabolic disease among children and adolescents. Proposed further research includes:

1. Investigation into the proximate causes of persistent childhood undernutrition and emerging adolescent obesity. Proposed studies may investigate causes of low birth weight and early stunting and the holistic role of HIV on undernutrition; and dietary patterns, physical activity patterns and sedentary behaviour among adolescents. It would be worthwhile to investigate the influence of food security using more detailed food security tool that measures different dimensions of food securtiy. Additionally, it would be worthwhile to investigate influence of other distal factors including occupation of the mother, income, and child support grants.
2. Investigation of body image among adolescents and its impacts on eating behaviour and consequent obesity, particularly among adolescent girls.
3. Longitudianl study to investigate applicability of developmental programming in this community and similar settings in LMICs given the coexistence of stunting with overweight/obesity in the same population.
4. Studies focusing on effective interventions to alleviate the double burden of malnutrition.
5. Investigation on the role of paediatric HIV infection on the nutritional status of children in a larger, randomly selected community based sample.

6. This study opens a window on the role of paediatric HIV testing with disclosure on caregiving practices and ultimately nutritional status and health outcomes of infected children, which needs more elaborate investigation.

Further research on some of these issues, including investigation of physical activity, dietary patterns and body image, is underway in the study area. Planned work includes intervention-research to promote adolescent weight control before and during pregnancy, thereby improving infant growth and development.

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Paper I

Kimani-Murage E, Kahn K, Pettifor J, Tollman S, Dunger D, Gomez-Olive X, Norris S. The prevalence of stunting, overweight and obesity, and metabolic disease risk in rural South African children. BMC Public Health2010;10(1):158.

Conference Proceedings

I. Kimani-Murage EW., Kahn K., Pettifor J.M., Tollman S.M. Goméz-Olivé F.X., Dunger D., Norris S.A. Age & sex patterns of the coexistence of under & over-nutrition in children and adolescents in contemporary rural South Africa. Distinguished poster presentation at the 19th International Congress of Nutrition (ICN), 4-9th October 2009, Bangkok, Thailand.

II. Kimani-Murage EW., Kahn K., Pettifor J.M., Tollman S.M. Goméz-Olivé F.X., Dunger D., Norris S.A. Coexisting under- & over-nutrition in rural South Africa. Oral presentation at the Biennial Wits School of Public Health Research Day, 14th May, 2009, Wits University, Johannesburg, South Africa.

III. Kimani-Murage E.W., Kahn K., Pettifor J.M., Tollman S.M. Goméz-Olivé F.X., Dunger D., Norris S.A. Age & sex patterns of the coexistence of under & over-nutrition in rural South Africa. Oral presentation at the 1st Wits Cross-Faculty Symposium, 7-8th November 2008, Wits University, Johannesburg, South Africa.

IV. Kimani-Murage E.W., Kahn K., Pettifor J.M., Tollman S.M. Goméz-Olivé F.X., Norris S.A. The paradox continues: evidence of coexisting under- & over-nutrition in rural south Africa. Oral presentation at the 4th Public Health Association of South Africa (PHASA) 2008 conference, 2-4th June 2008, Cape Town, South Africa.

The prevalence of stunting, overweight and obesity, and metabolic disease risk in rural South African children

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Key Words: Nutritional status, undernutrition, stunting, obesity, nutrition transition, double burden of malnutrition, rural, South Africa

Abstract

Background: Low- to middle-income countries are undergoing a health transition with non-communicable diseases contributing substantially to disease burden, despite persistence of undernutrition and infectious diseases. This study aimed to investigate the prevalence and patterns of stunting and overweight/obesity, and hence risk for metabolic disease, in a group of children and adolescents in rural South Africa.

Methods: A cross-sectional growth survey was conducted involving 3511 children and adolescents 1-20 years, selected through stratified random sampling from a previously enumerated population living in Agincourt sub-district, Mpumalanga Province, South Africa. Anthropometric measurements including height, weight and waist circumference were taken using standard procedures. Tanner pubertal assessment was conducted among adolescents 9-20 years. Growth z-scores were generated using 2006 WHO standards for children up to five years and 1977 NCHS/WHO reference for older children. Overweight and obesity for those <18 years were determined using International Obesity Task Force BMI cut-offs, while adult cut-offs of BMI =25 and =30 kg/m^2 for overweight and obesity respectively were used for those =18 years. Waist circumference cut-offs of =94cm for males and =80cm for females and waist-to-height ratio of 0.5 for both sexes were used to determine metabolic disease risk in adolescents.

Results: About one in five children aged 1-4 years was stunted; one in three of those aged one year. Concurrently, the prevalence of combined overweight and obesity, almost non-existent in boys, was substantial among adolescent girls, increasing with age and reaching approximately 20-25% in late adolescence. Central obesity was prevalent among adolescent girls, increasing with sexual maturation and reaching a peak of 35% at Tanner Stage 5, indicating increased risk for metabolic disease.

Conclusions: The study highlights that in transitional societies, early stunting and adolescent obesity may co-exist in the same socio-geographic population. It is likely that this profile relates to changes in nutrition and diet, but variation in factors such as infectious disease burden and

physical activity patterns, as well as social influences, need to be investigated. As obesity and adult short stature are risk factors for metabolic syndrome and Type 2 diabetes, this combination of early stunting and adolescent obesity may be an explosive combination.

Introduction

Understanding the prevalence and patterns of undernutrition, particularly stunting, the emergence of overweight/obesity in children and adolescents, and the concomitant risk for metabolic disease, is of criticial importance for public health policy. Undernutrition is a serious risk factor for ill health and contributes substantially to the burden of disease in low- to middle-income countries (LMICs) [1]. Increasing adverse ramifications of childhood undernutrition are recognised later in life, and include impaired cognitive development, poorer educational achievement and human capital formation [2], and greater risk for obesity [3].

A nutrition transition, often accompanied by changes in physical activity levels, is being experienced in LMICs. Nutrition transition refers to changes in diet composition from traditional diets that are primarily derived from plant-based food sources low in fat and high in fibre, to more "Western" diets that are high energy dense and low in fibre. This transition is driven by rapid economic transition, urbanisation, globalisation, technological and social changes [4, 5]. Nutrition transition typically begins with urban populations and those in higher social economic strata [4], but is not limited to these populations. Increased intakes of animal source foods and edible oils have been documented in less urbanised urban areas and more urbanised rural areas [6].

Nutrition transition is a major driving force behind the double burden of malnutrition, a phenomenon that has become important in LMICs where high levels of obesity have been documented despite persistence of undernutrition [4, 5]. Obesity has led to the increased public health importance of diet-related non-communicable diseases, such as cardiovascular diseases and

diabetes, in LMICs particularly in adults [1]. In line with the co-existence of undernutrition and obesity, a protracted-polarised model of epidemiologic transition has been documented in LMICs. In this non-classical model of epidemiologic transition, infectious diseases and undernutrition coexist with non-communicable diseases and persist over prolonged periods of time [7]. Therefore, both undernutrition-related diseases, infectious diseases and obesity-related diseases contribute substantially to the burden of disease in these societies [1].

The problem of obesity and related metabolic disease risk is not only experienced among adults. Paediatric obesity has been documented in LMICs and is the driving force behind paediatric metabolic syndrome risk that has become a growing public health concern in LMICs [8]. Childhoood/adolescent obesity is associated with health problems for the child/adolescent including heightened risk of psychosocial morbidity, cardiovascular complications, and type 1 and type 2 diabetes [9]. Of further concern is the fact that obese children and adolescents are likely to be obese adults at increased risk of cardiovascular diseases and other morbidity, premature death, and impaired social, educational and economic productivity [3, 9].

The World Health Organization (WHO) recommends more research into the frequency of risk factors related to the metabolic syndrome and their levels in LMICs [1]. Given that the pace and nature of transitions vary across geo-cultural settings, local data and context is increasingly stressed. This is particularly so because such information is essential to local programming and policy. The aim of this study is to investigate the prevalence of stunting and overweight/obesity by age and sex and to estimate the risk for metabolic disease in a group of children and adolesents aged 1-20 years randomly selected from a health and socio-demographic surveillance site in Agincourt, rural South Africa. We postulate that in rural South Africa stunting remains a concern among children, and that the transition to an urban profile with regards to overweight and obesity is advanced.

Data and Methods

Study Setting and Population

This study was conducted in rural northeast South Africa, in the Agincourt sub-district, Mpumalanga Province, alongside the country's border with Mozambique. Agincourt is a semi-arid setting, situated in the former Gazankulu homeland. The study was nested within the Agincourt health and socio-demographic surveillance system (HDSS), of the University of the Witwatersrand. Established in 1992 and covering the entire Agincourt sub-district, the Agincourt HDSS follows some 70,000 people living in 11,700 households in 21 contiguous villages. The population comprises Tsonga-speaking people, some 30% of whom are of recent Mozambican origin having entered South Africa mainly as refugees in the early to mid-1980s following the civil war in Mozambique. The Mozambicans are also Tsonga-speaking, have widely intermarried with the host South African population, and exhibit similar cultures.

The area is characterised by high levels of poverty: Mpumalanga province has one of the highest poverty rates in South Africa, at 64% [10]. There are high levels of unemployment: strict unemployment (excluding underemployment) is estimated at 29% for men and 46% for women [11]. Labour migration, mainly circular rural-urban migration, is widespread involving up to 60% of working age men and growing numbers of women [11]. Additionally, government support grants including the child support grant and pension for older people are an important source of income for many families. Being in a former homeland, the land is subdivided into plots too small to support subsistence farming. Housing material varies from traditional mud houses to brick houses. Piped water is available at community level, but there are frequent water shortages in most villages. Sanitation is poor, particularly in the former refugee settlements, with pit latrines of varying types from traditional pit latrines to ventilated improved pit latrines being the main method of excreta disposal in the area. Although the situation has improved in the last few years, roads are largely untarred and there is limited public transport with the main means of

transport being privately owned taxis [12, 13]. The area has benefited from the recent national electrification program. Access to education has improved: literacy levels have improved post-apartheid in the younger generation aged up to 29 years, but high illiteracy levels remain among the older generation, reaching levels of almost 80% for those aged 60 years and above [11]. Health care services are limited in the area: a network of five primary care clinics refers to a larger public health centre; the nearest district hospital is 25 kilometres away. The area is characterised by a high prevalence of HIV/AIDS, slightly over 30% among pregnant women visiting public antenatal health clinics in the province [14]. The study area, Agincourt HDSS and local demographics are described in detail elsewhere [12].

Data collection

The study was conducted between April and July 2007. The Agincourt HDSS, a longitudinal community surveillance system acted as the sampling frame for the study. It involves a systematic annual recording of vital demographic events including births, deaths and migrations occurring in all households in 21 contiguous villages in Agincourt sub-district. The baseline census was conducted in 1992 and data are updated annually. The study sample comprised children and adolescents aged 1-20 years selected from the entire population within this age spectrum in the Agincourt HDSS as at March 2007 (n=34775; 50% boys and girls respectively). For analysis and documentation purposes, the ages were truncated to full years; thus, for example, 20 years refers to participants aged 20.0–20.9 years. Four thousand children and adolescents were targeted, comprising 100 males and 100 females for each year of age. We oversampled 10-15 children per age-sex group to counter possible non-participation. Thus a total of 4658 children were randomly selected from the Agincourt HDSS database. Only children who had lived in the study area at least 80% of the time since birth, or since 1992 when enrolment into the Agincourt HDSS began, were included. A random sample of children was drawn from each age-sex-village stratum in proportion to the population size of the village.

Written informed consent was obtained from the parent/caregiver of children aged 1-17 years and from adolescents 18-20 years themselves. Consent was obtained during household visits on weekdays, and participants were invited to data-collection camps over the weekends and holidays at centrally located schools within the study villages. Assent was also obtained from those aged 9-17 years prior to data collection. Ethical clearance was granted by the University of the Witwatersrand Committee for Research on Human Subjects, Medical (M070244).

Anthropometric measurements were carried out on all children and adolescents aged 1-20 years, and pubertal assessments were done on those 9-20 years old. Height was measured using a stadiometer (Holtain, UK) calibrated in millimeters. For all children aged less than 24 months, the determination of length was done using an inelastic tape measure (Holtain, UK), in a recumbent position on a flat surface. Weight in kilograms (to one decimal point) was determined using a mechanical bathroom scale (Hanson, UK). Waist circumference was measured in milimetres using an inelastic tape measure (Holtain, UK), at the natural waist (midway between the tenth rib and the illiac crest) with the participant in a standing position. All measurements were carried out according to standard procedures [15].

Pubertal assessment in children 9 years and older was obtained using the Tanner 5-point pubertal self-rating scale which has been validated for Black South Africans [16]. This self-administered questionnaire was conducted for males and females separately, with the assistance of same-sex interviewers who explained how to complete the assessment prior to the participants completing the questionnaire. The five Tanner stages reflect physical development based on external primary and secondary sex characteristics: pubic hair in girls and boys, breast development in girls and genitalia in boys [17]. Genital development in boys and breast development in girls were used to define the stages in this study.

Data quality

A team of 12 fieldworkers was carefully trained by experts in anthropometric measurements. To minimise fieldworker variation, each fieldworker specialised in a specific measurement and collected the data on all study participants. Coefficient of variation for anthropometric measurements was determined before and towards end of the study period; on average, the coefficient of variation towards the end of the study ranged between <1% and 3% for the different measurements.

Data analysis

Weight-for-age z-scores (WAZ), height-for-age z-scores (HAZ) and weight-for-height z-scores (WHZ) for children up to 60 completed months were generated using the World Health Organization (WHO) 2006 growth standards with the WHO Anthro 2005 program, Beta Version [18]. Z-scores for those aged 5-17 years were determined using the National Center for Health Statistics (NCHS)/WHO reference. For the WHO standards, weight-for-length standards range from 45 to 110cm (for children aged younger than 24 months) while weight-for-height standards (for children 24-60 months) range from 65 to 120cm for both sexes. For the NCHS/WHO reference, weight-for-length reference ranges from 49 to 103cm and weight-for-height 55 to 145cm for boys (up to 11 years approximately); while for girls, weight-for-length reference ranges from 49 to 101cm and weight-for-height 55 to137cm (up to 9 years approximately). Thus, for the purpose of comparisons by sex, WHZ scores were calculated for all children up to 9 years.

Overweight and obesity in children 2-17 years were determined using the absolute age and sex specific cut-offs for Body Mass Index (BMI) recommended by the International Obesity Taskforce (IOTF) [19]. These are defined to pass through BMI of 25 and 30 kg/m^2 at 18 years for

overweight and obesity respectively. For adolescents 18-20 years, adult cut-off points of BMI =25 and =30 kg/m^2 for overweight and obesity respectively, were used [20].

Studies have shown that waist circumference is a better predictor of child and adolescent risk of metabolic diseases than BMI, or improves the ability of BMI in predicting this [21]. We used waist circumference alone and in combination with height in estimating the metabolic disease risk [22]. Waist-to-height ratio (WHtR) was generated by dividing waist circumference by height. The percentage of those at risk of metabolic diseases was estimated among adolescents who had attained at least Tanner stage 3 as it was assumed that these had attained approximately adult height. This was done using cut-offs of waist circumference of =94cm for males and = 80cm for females [23], and waist-to-height ratio of 0.5 for both sexes [22].

Data analysis was done using Stata version 10.0 (StataCorp LP, College Station, Texas, USA). Patterns of the prevalence of stunting (HAZ <-2), underweight (WAZ <-2), wasting (WHZ <-2), overweight and obesity by age and sex were determined. The Student t-test was used to test the differences between means across age-sex groups, and the chi-square test for differences in proportions by age and sex. A p-value of <0.05 was considered statistically significant.

Results

Nearly 80% (3511 participants) of the randomly selected sample participated in the study. Non-participation was due to failure to present for measurements after giving consent (9%), refusal to consent (1%), absence due to being in boarding school (8%), out-migration from study area (3%), and being away for other reasons (3%). From the 3511 participants, 22 were excluded from the analysis: pregnant adolescents (n=9), severely mentally and physically disabled children (n=11), one case with spurious date of birth, and one case with erroneous measurements. A total of 3489 children were included in the analysis: 1724 (49.4%) males and 1765 (50.6) females aged

between 1-20 years. Distribution of participants included in the analysis by sex and year of age is shown in Table 1 below. Further, the distribution of adolescents 9-20 years by Tanner pubertal stages is shown in Table 2. Most boys were in stages 1 and 2 while most girls were in stages 3-5. Only 5% of boys had reached stage 5.

Table 1: Distribution of study participants aged 1-20 years (n=3489), by age and sex, Agincourt sub-district, South Africa, 2007

Age (mean)	**Boys**		**Girls**	
	N	**%**	**N**	**%**
1(1.6)	70	4.1	67	3.8
2(2.5)	83	4.8	77	4.4
3(3.5)	103	6.0	91	5.2
4(4.5)	82	4.8	98	5.6
5(5.5)	87	5.1	86	4.9
6(6.5)	104	6.0	94	5.3
7(7.5)	91	5.3	110	6.2
8(8.6)	111	6.4	97	5.5
9(9.5)	90	5.2	100	5.7
10(10.5)	98	5.7	101	5.7
11(11.5)	105	6.1	97	55
12(12.5)	96	5.6	89	5.0
13(13.5)	94	5.5	97	5.5
14(14.5)	78	4.5	89	5.0
15(15.5)	82	4.8	99	5.6
16(16.5)	74	4.3	94	5.3
17(17.5)	69	4.0	67	3.8
18(18.5)	80	4.6	63	3.6
19(19.5)	70	4.0	67	3.8
20(20.6)	57	3.3	82	4.7
	1724		1765	

Table 2: Distribution of adolescents aged 9-20 years by sex and pubertal stage (n=2006), Agincourt sub-district, South Africa, 2007.

	Boys		Girls		Significant difference by sex (P-value)
Stage	**Mean age (SD)**	**N (%)**	**Mean age**	**N (%)**	
1	11.3 (1.5)	254 (26)	10.5 (1.1)	156 (15)	P<0.0001
2	13.3 (2.4)	296 (30)	12.0 (1.7)	186 (18)	P<0.0001
3	16.4 (2.3)	188 (19)	14.6 (2.4)	243 (24)	P<0.0001
4	18.1 (1.9)	193 (20)	16.9 (2.3)	306 (30)	P<0.0001
5	18.5 (1.8)	45 (5)	18.3 (2.0)	139 (14)	P=0.3954
Total	14.1 (3.3)	976(49)	14.1 (3.4)	1030(51)	

Prevalence of stunting, underweight and wasting by age and sex

Figure 1 shows the prevalence of stunting, underweight and wasting for boys and girls at each age, with the level of significance by sex indicated by an asterisk on the bars. The prevalence of stunting fell from 32% at 1 year to plateau at approximately 3-6 % from 5 years, before rising to 14-15% in boys during adolescence between years 14 and 15. Stunting was significantly greater in boys than girls at 6, 14 and 15 years (P<0.0500 respectively). Stunting was the most prevalent form of undernutrition for younger children aged 1-4 years at 18% (Table 3).

The prevalence of underweight in younger children ranged between 6 and 14% for children 1-6 years, was lower for children between ages 7 and 12 years, and peaked at 19% in boys aged 14 years. The prevalence of underweight was significantly higher in boys than in girls at ages 5, 13, 14 and 15 (p<0.0500).

The prevalence of wasting was uncommon at age 1 year but increased to approximately 4-9% between 2-9 years. There was no difference in wasting by sex.

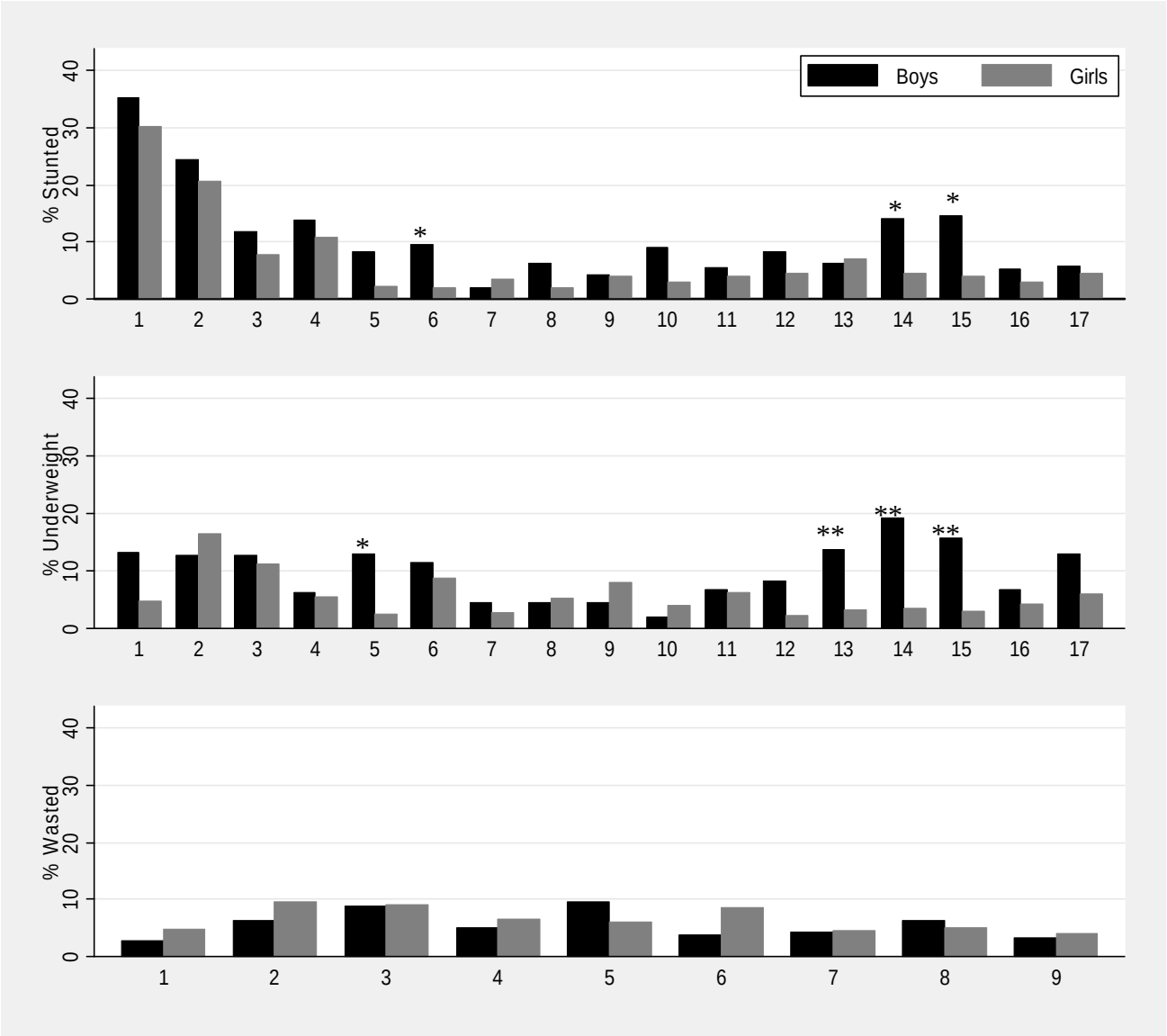

Figure 1: Prevalence of stunting and underweight for children aged 1-17 years (n=3070) and wasting for children aged 1-9 years (n=1641) by sex, Agincourt sub-district, South Africa, 2007. (Significant difference by sex: *P-value <0.05, **P-value <0.01, ***P-value<0.001)

Prevalence of stunting, underweight and wasting by Tanner pubertal staging and sex

Figure 2 shows the prevalence of stunting, underweight and wasting in children at Tanner stages 1-5, with the level of significance by sex indicated by an asterisk on the bars. There was no significant difference in stunting by sex at the various Tanner stages. Stunting was highest at Tanner stage 1 for both girls and boys at an average of 9%, and reduced with increasing stage to about 1% at Tanner stage 5. Boys at Tanner stage 2 and 3 were significantly more underweight than girls at the same stage; 11% vs. 4% (p=0.0080) and 10% vs. 2% (p=0.0010) respectively.

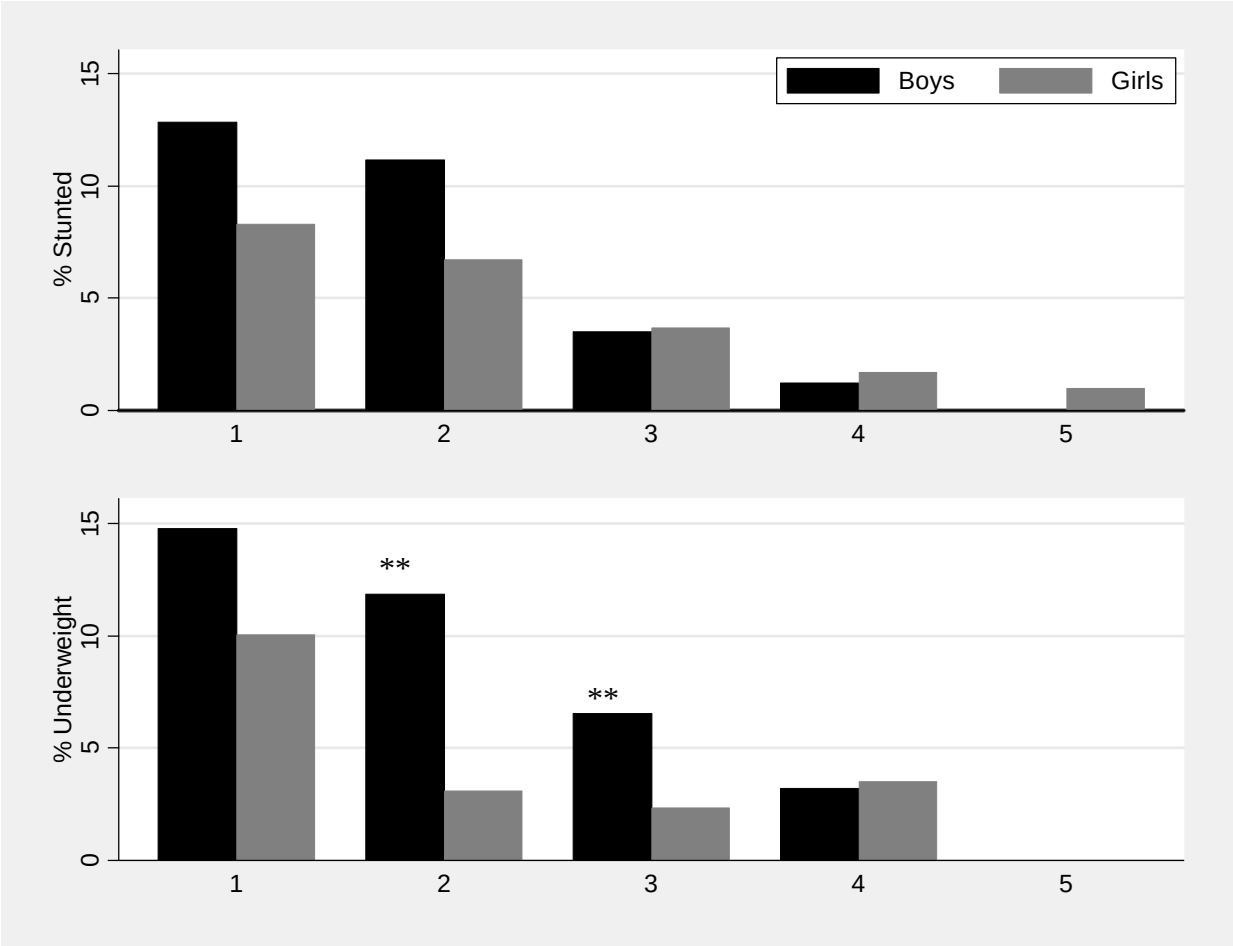

Figure 2: Prevalence of stunting and underweight for adolescents aged 9-20 years (n=2006) by Tanner stage and sex, Agincourt sub-district, South Africa, 2007. (Significant difference by sex: **P-value <0.01)

Prevalence of overweight and obesity by age and sex

Figure 3 shows the prevalence of overweight and obesity by age and sex with the level of significance by sex indicated with an asterisk on the bars. The prevalence of overweight and obesity was moderate in early childhood and low in late childhood, and remained so in older boys. However, the prevalence rose progressively in girls aged 10 years and older. Consequently, girls had significantly higher prevalence of combined overweight and obesity (P<0.05) than boys at ages 10 and 12-20; at age 15 years, significance was borderline (p=0.05). From age 14, overweight and obesity averaged some 18% in females compared to 4% in males, reaching approximately 20-25% in late adolescence in girls (Figure 4).

Co-existence of stunting and combined overweight and obesity in the same child was common in children aged less than five years (18%), but was uncommon in older children aged 5-9 years (5%) and adolescents aged 10-20 years (3%).

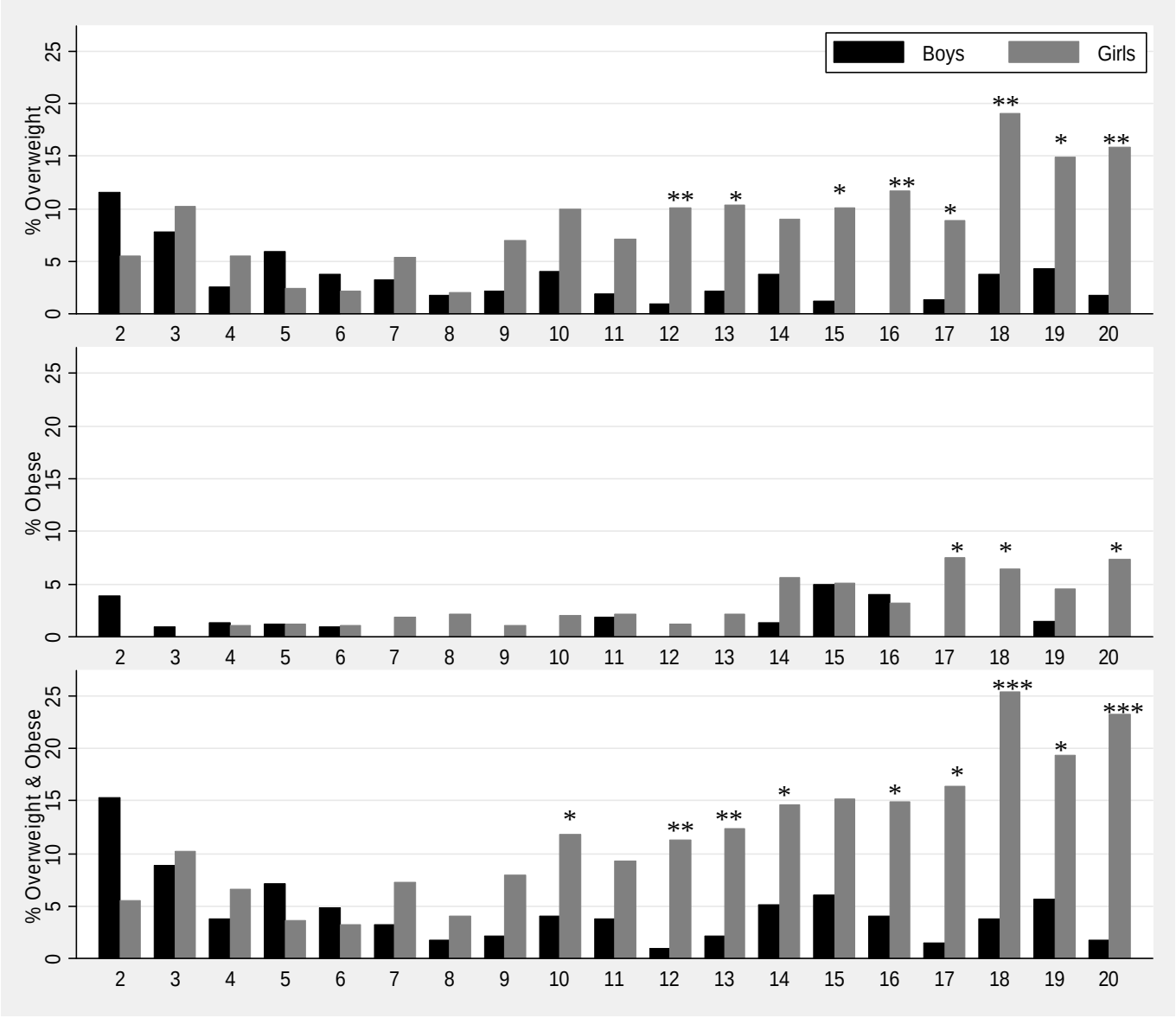

Figure 3: Overweight and obesity for children aged 2-20 years (n=3358) by sex. (Significant difference by sex, Agincourt sub-district, South Africa, 2007. (Significant difference by sex: *P-value <0.05, **P-value <0.01, ***P-value<0.001)

Prevalence of overweight and obesity by Tanner stages

Figure 4 depicts the relationship between the prevalence of overweight and obesity with Tanner pubertal stage in girls and boys. Combined overweight and obesity in girls was low in the earlier stages of puberty, but increased markedly during the later stages (from 7% to 35%); while in boys the prevalence remained low throughout the stages. The prevalence of combined overweight and obesity was significantly different between males and females at Tanner stages 3, 4 and 5 ($p<0.0010$ respectively).

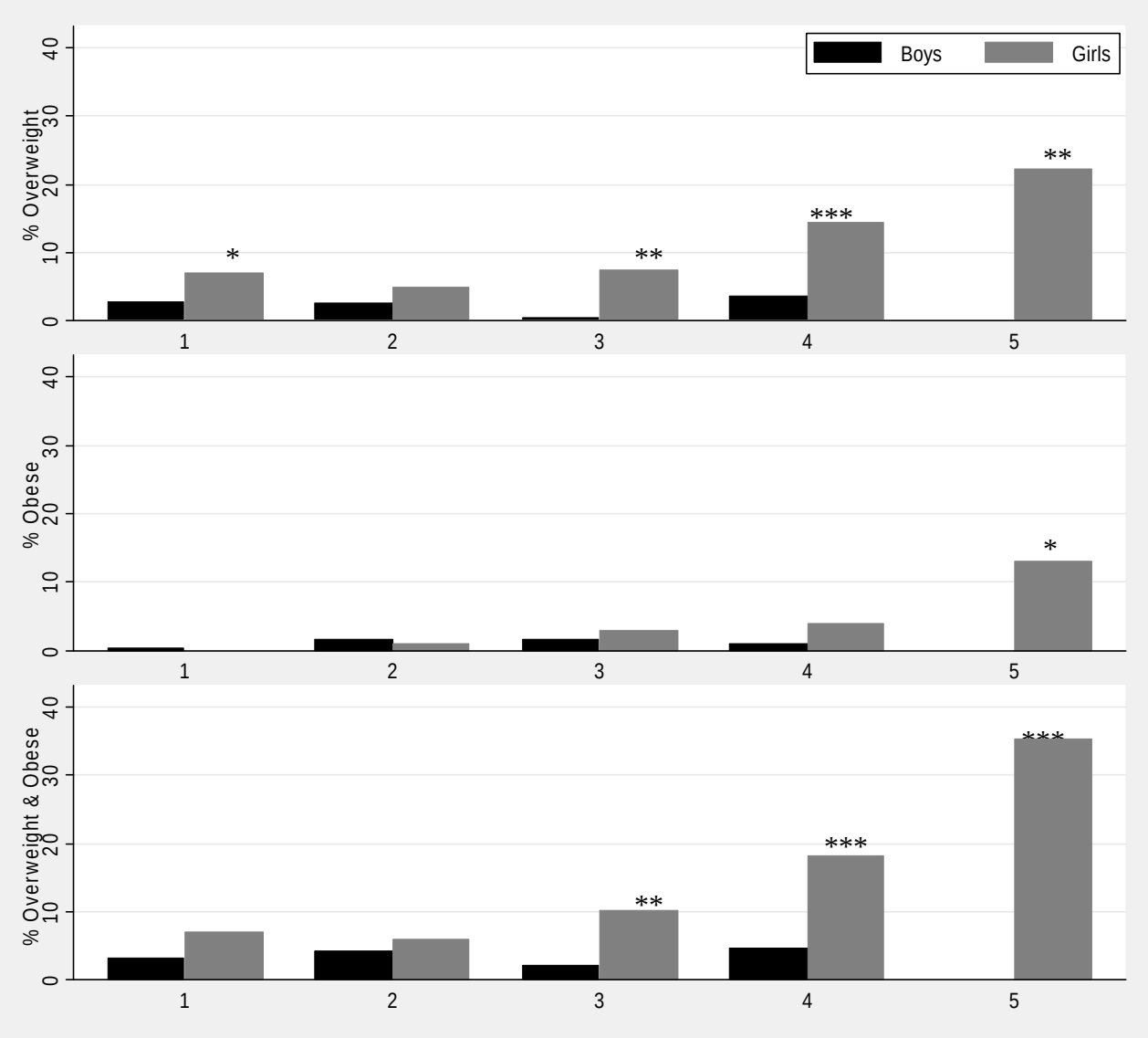

Figure 4: Overweight and obesity for adolescents aged 9-20 years (n=2006) by Tanner pubertal staging and sex, Agincourt sub-district, South Africa, 2007. (Significant difference by sex: *P-value <0.05, **P-value <0.01, ***P-value<0.001)

Risk for metabolic disease

Risk for metabolic disease, defined by central obesity using waist circumference and WHtR cut-offs [22, 23] among adolescents at Tanner stages 3-5, is presented by sex and pubertal stage in Figure 5. Using the waist circumference cut-offs, about 10% of adolescents were potentially at risk of metabolic disease; significantly higher proportion of girls (16%) than boys (1%) ($p<0.001$). Similarly, using the waist-to-height cut-offs, 10% of adolescents were potentially at risk with significantly higher proportion of girls (15%) than boys (3%) ($p<0.001$). The prevalence of risk using the different cut-offs increased with increasing pubertal stage in girls: 5% in girls at Tanner stage 3 using the waist circumference cut-offs, increasing to 35% at Tanner stage 5. There were significant differences by sex across all the Tanner stages using the waist circumference and WHtR cut-offs ($p<0.05$ at all stages respectively). Surprisingly, no boys were at risk of metabolic disease in Tanner stage 5 using the two cut-offs. However, there were fewer boys (n=45) who had attained this pubertal stage compared to girls (n=139).

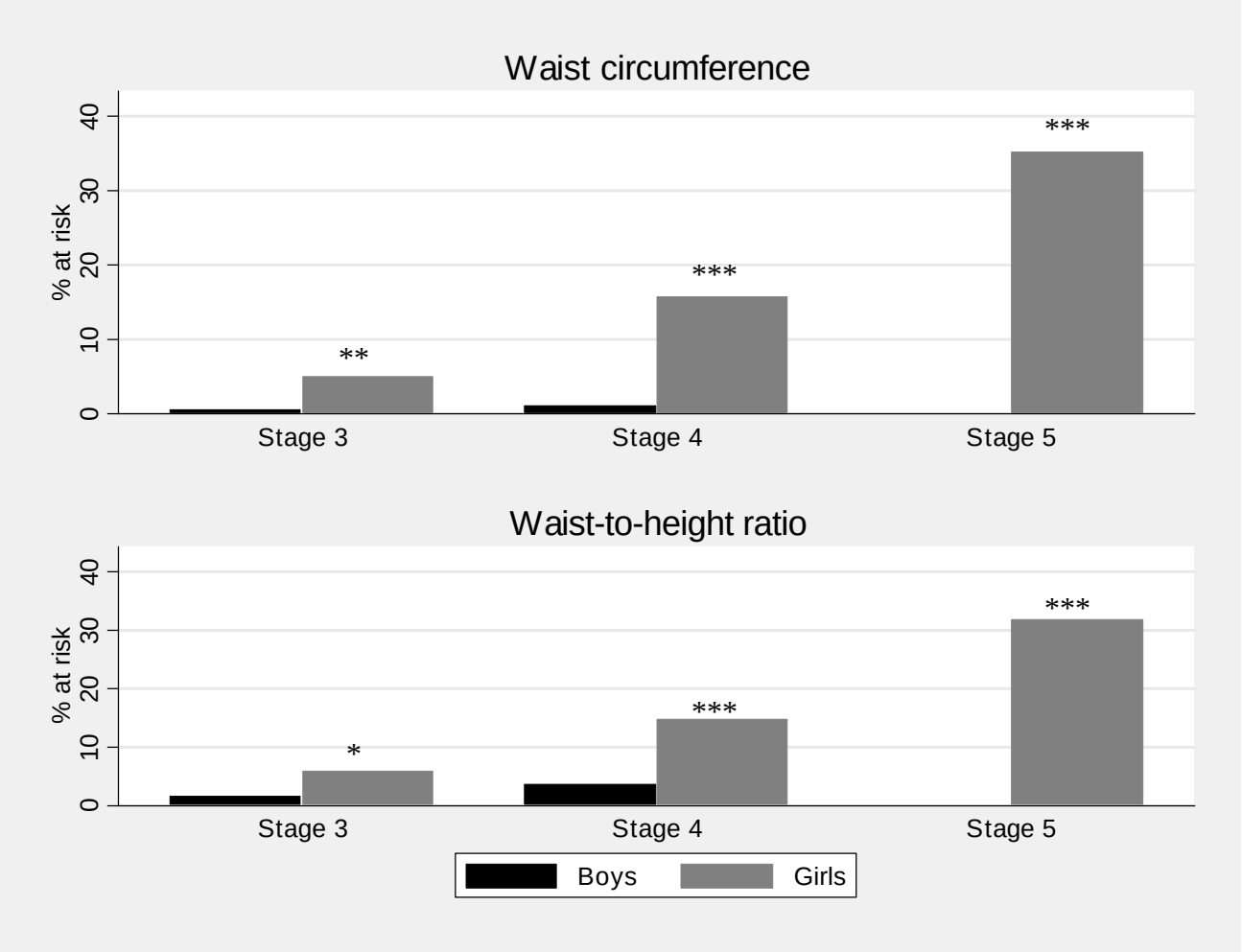

Figure 5: Metabolic disease risk using waist circumference and waist-to height ratio cut-offs for adolescents in tanner stages 3-5 (n=1114) by Tanner stage and sex, Agincourt sub-district, South Africa, 2007. (Significant difference by sex: *P-value <0.05, **P-value <0.01, ***P-value<0.001)

Discussion

This study presents evidence of a double-pronged problem of malnutrition; undernutrition and overweight/obesity in children and adolescents living in a rural South African community. This phenomenon is evident in societies undergoing nutrition transition in LMICs [4, 5].This study also documents noteworthy levels of overweight and obesity and central obesity among adolescent girls, indicating an elevated risk for metabolic disease. These findings are relevant to the heightened public health interest in paediatric metabolic syndrome in LMICs [8]. Both undernutrition and overnutrition traverse the life course and are important both at the individual and national level [2, 9, 24]. Further, both paediatric obesity and adult short stature are risk factors for the metabolic

syndrome and Type 2 diabetes in adulthood [9, 25]. Hence the combination of early stunting and adolescent obesity raises critical concerns. The study calls for urgent evidence-based policy development and interventions to address the dual problem of malnutrition in rural South Africa.

The levels of undernutrition in young children in this rural population correspond with earlier findings in South Africa [26-29] (see Table 3). They indicate the persistence of undernutrition in rural communities despite recent efforts to address household food insecurity, in part through the introduction of child support grants and old age pensions. Despite South Africa being a middle-income country, food insecurity remains a problem with some 35% of the total population considered food insecure [30]. The Agincourt area is typical of former apartheid homeland areas with a limited food production base. Located in geographically inhospitable areas, land is sub-divided into plots that are generally too small to support subsistence agriculture. This results in people having to rely substantially on purchased food which – in an area where people have low purchasing power – may result in food insecurity and consequent undernutrition. The poor nutritional outcomes shown in our study participants may not only be associated with the quantity of food but also the quality. Food variety and dietary diversity, which are associated with nutritional status of South African children, are limited in poor communities in South Africa [31]. The potential role of HIV and AIDS in the persistence of undernutrition in our study community cannot be underestimated. The high prevalence of HIV among women of child bearing age [14] indicates that many households are HIV affected. HIV and AIDS has an extensive effect on food security as it undermines the ability of households to provide for their basic needs [32]. Research in the study area shows that adult mortality, particularly that of a male wage-earner, affects household food security and that people often fall back on wild foods as a coping strategy [33]. Death of a mother has been associated with a fourfold increase in the odds of child undernutrition in the study area [34].

The results show higher prevalence of undernutrition amongst adolescent boys compared to girls. This confirms findings on adolescents in other South African studies [35] and on younger children elsewhere in sub-Saharan Africa [36]. The differential prevalence of undernutrition by sex in our study is likely to be due to delay in the pubertal growth spurt in boys compared to the reference group. This occurs where undernutrition is prevalent [37]. Other studies in South Africa have documented delayed pubertal development for children in rural areas compared to their urban counterparts [38]. Other factors may contribute to these differences because even after stratifying by pubertal stage, boys at Tanner stages 2 and 3 still showed significantly higher levels of underweight compared to girls in the same stage. Evidence amongst younger children indicates that disproportionate male undernutrition occurs in households with low socio-economic status; in better off households, the sex difference disappears [39]. Further investigations into the sex differences of malnutrition during adolescence in our study may be required.

In addition to the substantial prevalence of undernutrition documented in this study are noteworthy levels of overweight and obesity among adolescents, particularly girls. The levels of overweight/obesity are comparable to those documented in other rural areas in South Africa [40]. These levels are, however, lower than those recorded in various national surveys (Table 3) [26, 28, 41], indicating that there may be areas with very high levels. The South African Youth Risk Behaviour Survey 2002 documented a prevalence of combined overweight and obesity of 21% among adolescents in grades 8-11 (approx 13-19 years) nationally; 7% in boys and 25% in girls [41]. Our study documented a prevalence of about 10% in this age group; 4% in boys and 16% in girls. .

Table 3: Comparison of Prevalence of malnutrition in current study with national studies in South Africa

Study	**Population (n)**	**Reference**	**Stunted %**			**Underweight %**			**Wasted %**			**Overweight %**			**Obese %**		
			U	R	N	U	R	N	U	R	N	U	R	N	U	R	N
SAVACG (1994)	6-71 mo (11430)	WHO/NCHS	16	27	23	7	11	9	2	3	3						
NFCS (1999)	1-9 y (2894)	WHO/NCHS IOTF	17	27	22	8	13	10	2	5	4	13	12	12	6	4	5
YRBS (2002)	Approx. 13-19 y (9224)	WHO/NCHS IOTF	-	-	11	-	-	9	-	-	4	-	-	17	-	-	4
DHS (2003)	<5 y (1159)	WHO/NCHS	27	28	27	12	11	12	6	5	5	-	-	-	-	-	-
NFCS (2005)	1-9 y (2469)	WHO/CDC IOTF	16	20	18	9	9	9	5	4	4	10	10	10	4	4	4
Agincourt (2007)	1-20 y (3489)	WHO WHO/NCHS IOTF	-	8	-	-	7	-	-	6	-	-	6	-	-	2	-
	1-4 y (671)		-	18	-	-	10	-	-	7	-		7	-	-	1	-
	5-9 y (970)		-	5	-	-	6	-	-	6	-		4	-	-	1	-
	10-14 y (944)		-	7	-	-	7	-	-	-	-		6	-	-	2	-
	15-20 y (904)		-	6	-	-	8	-	-	-	-		8	-	-	4	-

U=Urban; R=Rural; N=National

Sources:

SAVACG (1994): The South African Vitamin A Consultative Group, 1995 [29]

NFCS (1999): Labadarios et al., 2005 [28]

YRBS (2002): Reddy et al., 2008 [41]

DHS (2003): Department of Health, 2003 [27]

NFCS 2005: Department of Health, 2007 [26]

Agincourt (2007): Current study

As with overweight and obesity, prevalence of central obesity was substantial particularly amongst adolescent girls. Central obesity, measured using waist circumference alone or in combination with other measures, is an integral risk indicator for metabolic syndrome [23]. The

risk in this study increased with sexual maturation, indicating higher risk as the adolescents transition to adulthood. The finding of a substantial level of central obesity is important as childhoood/adolescent metabolic syndrome risk is increasingly becoming a concern in LMICs [8]. Childhoood/adolescent overweight/obesity is associated with many health problems for the child/adolescent including heightened risk of psychosocial morbidity, asthma, orthopaedic difficulties, cardiovascular complications, and type 1 and type 2 diabetes [9]. Further, overweight/obese children and adolescents are likely to be obese adults at increased risk of cardiovascular and other morbidity, premature death, and impaired social, educational and economic productivity [3, 9]. Risk components for the metabolic syndrome have been tracked from childhood to adulthood in several studies [42]. This emphasizes the importance of identifying these risk factors and addressing the problem early during childhood to prevent transfer of these risks to adulthood.

The higher prevalence of obesity among adolescent girls compared to boys in this study is in keeping with many studies in other LMICs [43] and in South Africa in particular [35]. Several factors may explain these sex differences. Biologically, energy needs differ for boys and girls and also in relation to rate of growth. Further, timing of sexual maturation differs by sex [44]. Behavioural factors are also important in explaining the sex differences: boys are generally more physically active compared to girls especially during adolescence [45, 46]. Concerns about body image, particularly among adolescent girls, may lead to problematic eating behaviours such as irregular meals which may result in increased weight gain [47]. Differential problematic eating behaviours by sex have been reported among South African youth [48].

The phenomenon of a double burden of malnutrition documented in this study is becoming increasingly important in LMICs undergoing nutrition transition [4, 5]. Several factors shed light on why this phenomenon is occuring in rural South Africa. Literature on early developmental

programming describes how nutritional deprivation during the foetal period and early childhood leads to adaptations that may result in obesity during later life [3]. This may partly explain the co-occurrence of stunting in early childhood with overweight and obesity during adolescence in our study. Further, change of food cultures and lifestyle may also play a major role. Studies on urbanisation in South Africa have reported decreased intake of staple foods including maize meal, and increased intake of energy-dense foods including added fats and oils and animal-derived foods [49]. Similar findings have been documented in other LMICs undergoing nutrition transition [4]. Over-reliance on energy-dense processed foods, purchased due to insufficient local food production, may be a key factor in the development of adolescent overweight and obesity in the study area. Extensive labour migration to larger towns [11] facilitates the transfer and introduction of urban practices to rural settings with consequent change in diet and lifestyle. Women's participation in the labour force, increasingly reported in the study area, may also impact on food supply and diet [11].

Physical inactivity and sedentary lifestyles are associated with childhood/adolescent overweight and obesity [50]. National electrification in South Africa in the last few years, with consequent increase in televisions at home, may have resulted in decreased physical activity. Studies in South Africa have reported decreased physical activity among adolescents [45, 46]. Increased TV viewing by children/adolescents may also be associated with increased consumption of unhealthy foods seen in TV advertisements [51]. Length of TV viewing by children/adolescents has been associated with higher consumption of fast foods and other high energy dense food and lower intake of fruits and vegetables [52].Contribution of these factors to the patterns of obesity we have observed need further investigations.

Despite the important findings in our study, a few limitations should be noted. This study did not collect data on food intake and physical activity patterns which would help explain the findings.

However, further work is underway to determine factors associated with nutritional status in the study area, including dietary patterns and physical activity levels. Owing to the Agincourt HDSS sampling frame used, there were no infants in the study sample. This may have implications for findings, particularly with regards to undernutrition. There was higher non-participation among older adolescents. This may indicate over-representation of the study sample by younger children and may have implications for the overall findings. Despite these limitations, it is important to point out the strength of the sampling procedure employed. The sampling was purely random, using an existing sampling frame, and representative of the study area as the study sample was drawn from the various villages in proportion to the population size of the villages. The findings provide useful picture of patterns of nutritional status among children and adolescents in rural South Africa. They also raise important questions that could be followed up in future studies.

Our findings have implications at individual, community and national levels that traverse the life course. The importance of both paediatric undernutrition and overweight/obesity cannot be overemphasised [1, 2, 8]. The overweight/obesity prevalence we have observed in this study, particularly in adolescent girls, may partly contribute to the high levels of overweight/obesity reported in South African adults, particularly in women [27]. The level of central obesity in adolescent girls indicates risk of later metabolic disease. This is of major public health importance as South Africa is undergoing an epidemiologic transition with chronic non-communicable diseases associated with obesity contributing markedly to the burden of disease in this community and other parts of South Africa- despite the burden due to infectious diseases and undernutrition [53-55]. At national level, undernutrition may ultimately affect the gross domestic product through lowered economic productivity – malnourished children are more likely to have poor educational outcomes leading over time to lower incomes, higher fertility, and suboptimal care for their children, thereby contributing to the intergenerational transfer of poverty [2, 24].

In conclusion, child growth and nutrition in rural South Africa is clearly shifting along the rural-urban continuum and is tending towards an urban-like profile. Persisting prevalence of undernutrition, particularly stunting, at an early age suggests inadequate interventions to address food insecurity and undernutrition. It also indicates possible need to intervene during the perinatal period. The prevalence of substantial levels of overweight and obesity in the same community presents a multifaceted policy and programme challenge. It is likely that this profile relates to changes in nutrition and dietary patterns, but variation in other factors such as infectious disease burden and physical activity including exercise, as well as social influences, need to be investigated. We therefore recommend a scaling up of research and programme evaluation in order to inform policy on effective intervention strategies that can address the double-pronged problem of malnutrition.

List of Abbreviations

HDSS	Health and socio-demographic surveillance system
AIDS	Acquired immune deficiency syndrome
BMI	Body mass index
CDC	Centers for Disease Control and Prevention
Cm	Centimetre(s)
DALYs	Disability-adjusted life years
DoH	Department of Health
HAZ	Height-for-age z-scores
HIV	Human immunodeficiency virus
Kg	Kilogram(s)
IOTF	International Obesity Taskforce
LMICs	Low-to-middle income countries

M	Metre(s)
MDGs	Millennium development goals
NFCS	National food consumption survey
NCHS	National Center for Health Statistics
SAVACG	The South African Vitamin A Consultative Group
UK	United Kingdom
USA	United States of America
USD	United States dollar
WAZ	Weight-for-age z-scores
WHO	World Health Organization
WHtR	Weight-for-height ratio
WHZ	Weight-for-height z-scores
YRBS	Youth risk behaviour survey

Competing Interests

None to declare

Authors' Contributions

EWK-M: Design of the study, project management, training and supervising fieldworkers, data management and analysis, writing of the manuscript and approval for submission

KK: Design of the study, overall project co-ordination, reviewing of the manuscript and approval for submission

JMP: Design of the study, review of the manuscript and approval for submission

SMT: Design of the study, review of the manuscript and approval for submission

DD: Design of the study, review of the manuscript and approval for submission

FXG: Design of the study, training of field workers, implementation and supervision of field work, review of the manuscript and approval for submission.

SAN: Design of the study, overall project management, reviewing of the manuscript and approval for submission

Acknowledgements

We acknowledge funding from the National Research Foundation (NRF) and the Medical Research Council (MRC), South Africa. The Agincourt health and socio-demographic surveillance system is funded by the Wellcome Trust, UK (069683/Z/02/Z) and is a member of the INDEPTH Network. Elizabeth Kimani-Murage has a PhD fellowship funded by the Flora and William Hewlett Foundation, USA, while Dr. Shane Norris holds a Wellcome Trust Research Fellowship. We acknowledge logistical support from the MRC/Wits Rural Public Health and Health Transitions Research Unit (Agincourt) during data collection and from the African Population and Health Research Center, Kenya during preparation of this manuscript. We acknowledge Mark Collinson and Kerstin Klipstein-Grobusch for their technical contributions during design of the study. We acknowledge the data collection team and the LinC office team at the MRC/Wits Rural Public Health and Health Transitions Research Unit (Agincourt) specifically Rhian Twine, Geoffrey Tibane and Audrey Khosa for their role in community mobilisation. We also acknowledge the training team and the data entry team from the Birth To Twenty program, University of the Witwatersrand, South Africa funded by the Wellcome Trust, UK (077210/Z/05/Z). This paper was presented and received useful comments at the Public Health Association of South Africa (PHASA) conference, 2008, the INDEPTH Network annual general meeting, 2008, and the University of the Witwatersrand inter-faculty post-graduate symposium, 2008. It was also presented and reviewed in a seminar at the School of Public Health, University of the Witwatersrand, South Africa.

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Paper II

Kimani-Murage EW., Norris S.A., Pettifor J.M., Klipstein-Grobusch K., Tollman S.M., Gómez-Olivé F.X., Dunger D.B., Kahn K. Nutritional status and HIV in rural South African children (Submitted, BMC paediatrics Journal)

Conference Proceedings

I. Kimani-Murage E.W., Norris S.A., Pettifor J.M., Klipstein-Grobusch K., Tollman S.M., Gómez-Olivé F.X., Dunger D.B., Kahn K. Patterns of malnutrition among 1-4 year children by HIV status and covariates of malnutrition in rural South Africa. Oral presentation at the INDEPTH AGM, 26-29th October, 2009, Pune, India.

II. Kimani-Murage E.W., Norris S.A., Pettifor J.M., Klipstein-Grobusch K., Tollman S.M., Gómez-Olivé F.X., Dunger D.B., Kahn K. Malnutrition Patterns by HIV Status for 1-4 Year Olds in Rural South Africa. Oral presentation at the Population Association of Southern Africa (PASA) conference, 8-10th July 2009, Cape Town, South Africa.

Nutritional status and HIV in rural South African children

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Abstract

Background: Achieving the Millennium Development Goals that aim to reduce malnutrition and child mortality depends in part on the ability of governments/policymakers to address nutritional status of children in general and those infected or affected by HIV/AIDS in particular. This study describes HIV prevalence in children, patterns of malnutrition by HIV status and determinants of nutritional status. Further, it examines the impact of HIV positive children on community-based nutritional assessments.

Methods: The study involved 671 children aged 12-59 months living in the Agincourt sub-district, rural South Africa in 2007. Anthropometric measurements were taken and HIV testing with disclosure was done using two rapid tests. Z-scores were generated using WHO 2006 standards as indicators of nutritional status. Linear and logistic regression analyses were conducted to determine determinants of child nutritonal status.

Results: Prevalence of malnutrition, particularly stunting (18%), was high in the overall sample of children. HIV prevalence in this age group was 4.4% (95% CI: 2.79 to 5.97). HIV positive children had significantly poorer nutritional outcomes than their HIV negative counterparts. The impact of paediatric HIV on nutritional status at community level was not significant. Besides HIV status, other significant determinants of nutritional outcomes included age of the child, birth weight, maternal age, age of household head, and area of residence.

Conclusions: This study documents poor nutritional status among children aged 12-59 months in rural South Africa. Although the impact of paediatric HIV on nutritional status at community level is low because the prevalence of HIV is low, it is an independent modifiable risk factor for poor nutritional outcomes. HIV therefore makes a significant contribution to nutritional outcomes at the individual level. Early paediatric HIV testing of exposed or at risk children, followed by appropriate health care for infected children, may improve their nutritional status and survival. However, aggressive HIV screening during community-based nutritional assessments is not indicated in settings with this level of HIV prevalence.

Key Words: Nutritional status, stunting, underweight, wasting, HIV, children, rural, South Africa, sub-Saharan Africa

Introduction

Achievement of two of the Millennium Development Goals (MDGs) aimed at reducing malnutrition and child mortality by 2015 will depend in part on the ability of governments/policymakers to address the health and nutritional status of all children in general and of children infected or affected by HIV/AIDS in particular. Though some gains have been made in reducing child malnutrition, millions of children are still malnourished: some 26% of children under five years suffered from malnutrition in developing countries in 2006 [1]. Malnutrition is a risk factor for poor cognitive development, reduced human capital, premature death and other health consequences [2-4]. HIV/AIDS, which is highly prevalent in sub-Saharan Africa [5], may complicate child malnutrition in settings with high HIV prevalence such as South Africa.

HIV/AIDS is associated with nutritional deficiencies in infected children [6] while undernutrition influences disease progression, increases morbidity and lowers survival of HIV infected persons [7]. Additionally, HIV/AIDS has enormous impact on food security of affected households [8, 9]. Other covariates of child malnutrition have been documented including child level factors such as age and birth weight; maternal level factors such as maternal age and education; household level factors such as food insecurity and social economic status; and community level factors such as sanitation and environmental factors [10-12]. Importance of these factors to nutritional status of children may vary with differing contexts, indicating the need for context-specific evidence.

South Africa, like neighbouring Southern African countries, is experiencing one of the most severe HIV epidemics in the world [5]. Nationally, 28% of pregnant women visiting public antenatal clinics are HIV infected [13]. Additionally, there are high levels of food insecurity at household level: about 35% of the total population lack food security, a vulnerability aggravated by HIV/AIDS in South Africa [14]. Malnutrition remains highly prevalent in South Africa particularly in rural areas [15]. It is against the backdrop of the dual burden of high HIV prevalence and high risk of malnutrition in South Africa, that this study was conducted.

The study investigates the prevalence of HIV infection among 12-59 months old children, patterns of nutritional status by HIV status, and determinants of malnutrition in this age group. The study further assesses the impact on nutritional outcomes of including HIV positive children in community-based nutritional assessments in settings with similar paediatric HIV prevalence. Technicalities of HIV testing of young children and ethical issues limit evidence on nutritional status of HIV positive children in randomly selected samples at population level; this is a key strength of this study. Our study thus makes an important contribution in establishing the wellbeing of HIV positive children in a community setting.

Data and Methods

Study Setting and Population

This study was conducted in the rural Agincourt sub-district of Mpumalanga Province, northeast South Africa, which borders Mozambique. It was nested within the Agincourt health and socio-demographic surveillance system (Agincourt HDSS), established in 1992 which covers the entire sub-district and follows some 70,000 people living in 11,700 households in 21 contiguous villages. The population comprises Tsonga-speaking people, some 30% of whom are of recent Mozambican origin, having entered South Africa mainly as refugees in the early to mid-1980s during the civil war in Mozambique. The area is dry with household plots too small to support

subsistence farming. The area is characterised by high levels of poverty; the province in which the study area is located has one of the highest poverty rates in South Africa, at 64% [16]. Labour migration is widespread involving up to 60% of working age men and growing numbers of women [17, 18]. A network of five primary care clinics refers to a larger public health centre; the nearest district hospital is 25 kilometers away. Thirty-two percent of pregnant women visiting public health clinics in the province hosting the study area (Mpumalanga province) are HIV positive [13].

The Agincourt Health and Demographic Surveillance System (HDSS)

The Agincourt HDSS is a multiround prospective community study and involves systematic annual recording of all births, deaths and migration events occuring in Agincourt since 1992. Individual characteristics including date of birth, sex, and nationality of origin are recorded. Additional data are collected as special census modules nested within the annual update rounds. These include education, child social grant uptake, union status and food security. An asset survey conducted in each household every two years gives a measure of household socioeconomic status. Detailed information on the Agincourt HDSS is provided elsewhere [19, 20].

Explanatory variables used in this study were obtained from the Agincourt HDSS: child's age and sex; birth weight; place of delivery; child's relationship to household head; age, nationality, highest education level, and marital/union status of the mother; mother's co-residence with child; age, sex and highest education level of household head; household food security and socio-economic status; and village of residence.

The food security data utilised in this study was collected in 2007 as a panel survey nested within the Agincourt HDSS. Food insecurity was defined as not having reported enough food to

eat either in the last one month or in the last one year, whereas food secure households were characterized as households reporting sufficient to eat both in the last one month and one year respectively.

Household wealth index was constructed from the 2007 survey [21], which documented type and size of dwelling; water and sanitation facilities; electricity; modern assets such as fridge and television; transport assets such as bicycle and car; communication assets such as cellphone; and livestock such as cattle. A summated absolute score for the wealth indicator was constructed. To begin, each asset variable was coded with the same valence (i.e. increasing values correspond to greater SES) and effectively given equal weight by rescaling so that all values of a given asset variable fall within the range (0, 1). Assets were then categorized into five broad groups – 'modern assets', 'livestock assets', 'power supply', 'water and sanitation' and 'dwelling structure'. For each household within each asset group, the rescaled asset values were summed and then rescaled again to yield a group-specific value in the range (0, 1). Finally for each household, these five group-specific scaled values were summed to yield an overall asset score whose value could theoretically fall in the range (0, 5). Household wealth tertiles were generated from the absolute SES score using the Stata's xtile command and labelled as most poor (lowest 1/3), middle class, and least poor (highest 1/3).

Growth Survey

We conducted a cross-sectional anthropometric survey between April and July 2007. This survey targetted 4000 children and adolescents aged between 1 and 20 years, who were permanent residents in the study area at the time of sampling and had lived in the study area at least 80% of their lives, since birth or since 1992 when the Agincourt HDSS started. A total of 2000 girls and 2000 boys were targetted, 100 participants in each age and sex group. The study sample was randomly selected from 14 villages using the Agincourt HDSSdatabase as the sampling frame.

The time between the most recent database and study fieldwork resulted in no participants under the age of one year. Hence for the purpose of this paper, children aged 12-59 months were included; a total of 671 children.

Invitation to participate was initiated during a home visit at which informed consent to participate in the growth survey was obtained from the caregiver (caregiver refers to mother or non-mother caregiver who was the usual carer of the child). Data were collected during weekends in schools centrally located within the study villages. Anthropometric measurements included height and weight: height was measured using a stadiometer (Holtain, UK) calibrated in millimeters. For all children aged less than 24 months, length was measured using an inelastic tape measure (Holtain, UK), in a recumbent position on a flat surface. Weight in kilograms (to one decimal point) was determined using a mechanical bathroom scale (Hanson, UK). All anthropometric measurements were taken according to standard procedures [22]. To standardise measurements and enhance quality, each measurement was conducted by a dedicated lay fieldworker specifically trained in the technique by experts in the field. Height-for-age z-scores (HAZ), weight-for-age z-scores (WAZ), and weight-for-height (WHZ) z-scores were generated using the WHO Anthro 2005 program, Beta Version, using the WHO 2006 standards [23]. These parameters were used to determine nutritional status: stunting, underweight and wasting were determined as z-scores < -2 respectively [24].

HIV testing of children aged 12-59 months was carried out after anthropometric measurements were taken. Informed consent for the HIV test was obtained separately from the earlier consent for anthropometric measurements. Pre-test counselling was given to the caregiver of the child before the test was done. Blood was obtained from each child through a finger prick. Two rapid tests: Uni-Gold^{TM} (Trinity Biotech, Bray, Ireland) and Determine^{TM} (Abbott, Wiesbaden, Germany) were performed concurrently in accordance with WHO recommendations for HIV

screening in children [25]. Of the 671 children aged 12-59 months in the study, 640 consented to testing, a 95% response rate. A child was defined as HIV negative if both tests were negative, HIV positive if both tests were positive, and indeterminate if either of the tests was negative and the other positive. The result was given to the caregiver if s/he wished to know the status. All but two respondents requested the result; one refused and one could not wait for the result due to other commitments but was informed later. All caregivers of HIV positive children and those with indeterminate results (only one) were counselled and referred for a confirmatory test, further counselling and other support at the nearest primary health care facility. Similarly, all children identified as malnourished were referred to local clinics for nutritional advice and support ; these had been fully briefed on the study.

Ethical Clearance

Ethical clearance for the two studies was granted seperately by the University of the Witwatersrand Committee for Research on Human Subjects, (Medical). Ethical clearance number for the 2007 growth survey is M070244, while for the Agincourt HDSS is M960720. Informed consent was obtained from the children's caregivers.

Data Analysis

Data analysis using Stata version 10.0 (StataCorp LP, College Station, Texas, USA) describes by HIV status, mean HAZ, WAZ and WHZ (and their standard deviations), as well as prevalence of stunting, underweight and wasting. T-test and oneway ANOVA were used to test for statistically significant differences in means by HIV status, while Chi-square test was used for proportions.

Univariate linear and logistic regression were done to investigate the association of independent variables, listed above, to nutritional outcomes. Missing values for each variable were allocated an independent category in the regression models to maintain all participants in the analysis. The variables affected include birth weight obtained from the Road-to-Health card (22% missing

values), household head education (10% missing values), mother's education (7% missing values), food security (6% missing values), socio-economic status (2.5% missing values), and mother's age, mother's nationality and household head relationship to child (<2% missing values each). Explanatory variables found to be significantly associated with the outcome variable at the 10% level of significance in the univariate analysis were included in the multivariate linear and logistic regression analysis. HIV status was maintained in all the models, being the key predictor of interest. A p-value of <0.050 was considered statistically significant.

Results

Characteristics by HIV status

This study involved 671 children aged 12-59 months in 2007: 338 (50.4%) boys and 333 (49.6%) girls. Of these, 612 were HIV negative, 28 HIV positive, and 31 were not tested (no consent for the test), resulting in a HIV prevalence of 4.4% (95% CI: 2.79 to 5.97) in this age group; 3.1% (95% CI: 1.20 to 5.03) in boys and 5.6% (95% CI: 3.10 to 8.20) in girls.

Children who were not tested had seemingly better nutritional outcomes generally than both HIV negative and HIV positive children (Table 1). The mean birth weight for all children was 3.1 kg (SD; 0.49) and 10% of children had low birth weight (<2.5 kg). HIV positive children had significantly lower mean birth weight compared to HIV negative children (p=0.029). Mothers of HIV positive children were significantly older than mothers of HIV negative children (p=0.029), with two-thirds being in the age category 25-34 years (67%). Mothers of HIV positive children had a significantly lower level of education compared to those of HIV negative children (p=0.017). Twenty one mothers did not co-reside with their children (3% of the total sample, 81% of whom had died). A significantly higher proportion of mothers of HIV positive children (p=0.018) did not co-reside with the child.

Nutritional outcomes

Mean height- and weight-for-age and weight-for-height z-scores were all significantly lower in HIV positive children compared to HIV negative children ($p=0.002$, $p=0.001$ and $p=0.047$, respectively). (Table 1).

Table 1: Characteristics of study participants by HIV status (n=671), Agincourt, South Africa (2007)

Characteristic	All [n=671]	HIV- [n=612]	HIV+ [n=28]	Unknown status [n=31]	P-Value [comparing all three categories]	P-value [comparing HIV- & HIV+ only]
Child Characteristics						
HAZ [mean (SD)] (n=670)	-0.96 [1.18]	-0.95 [1.20]	-1.60 [0.97]	- 0.70 [0.89]	0.007	0.002
WAZ [mean (SD)] (n=671)	-0.54 [1.17]	-0.52 [1.16]	-1.26 [1.31]	-0.21 [0.96]	0.001	0.001
WHZ [mean (SD)] (n=670)	-0.05 [1.35]	-0.04 [1.34]	-0.56 [1.55]	0.20 [1.32]	0.077	0.047
Child age in years [mean (SD)] (n=671)	2.6 [1.1]	2.6 [1.1]	2.6 [1.2]	2.8 [1.0]	0.618	0.560
Child Sex (%) (n=670)						
Boys (n=338)	50.3	50.8	35.7	54.8		
Girls (n=333)	49.6	49.2	64.3	45.2	0.259	0.118
Birth weight (continuous) [mean (SD)] (n=522)	3.1 [0.49]	3.1 [0.48]	2.9 [0.54]	3.2 [0.62]	0.062	0.029
Birth weight categories (%) (n=522)						
Low; <2.5 kg (n=54)	10.3	9.9	16.0	14.3	0.515	0.323
Normal; =2.5 kg (n=468)	89.7	90.1	84.0	85.7		
Maternal Characteristics						
Mother's age (%) (n=659)						
15-24 (n=77)	31.4	33.0	11.1	19.4		
25-34 (n=207)	42.0	40.1	66.7	45.2	0.029	0.017
35+ (n=175)	26.6	26.3	22.2	35.5		
Mother's Nationality (%) (n=658)						
South African (n=435)	66.1	65.3	59.3	87.1	0.033	0.517
Mozambican (n=223)	33.9	34.7	40.7	12.9		
Mother's Education (%) (n=625)						
None (n=83)	13.3	13.3	23.0	3.5		
Some education < completed secondary (n=381)	62.6	62.3	69.2	62.1	0.078	0.089
Secondary & Tertiary (n=191)	24.2	24.4	7.7	34.5		
Mother Union Status (%) (n=671)						
Currently in union (n=320)	47.7	48.2	39.3	45.2	0.626	0.356
Not in union (n=351)	52.3	51.2	60.7	54.8		

Table 1: Characteristics of study participants by HIV status (n=671), Agincourt, South Africa 2007)

Mother co-residence (n=671)						
Co-residing (n=650)	96.9	97.2	89.3	96.8	0.062	0.018
Not co-residing (n=21)	3.1	2.8	10.7	3.3		
Delivery place (%) (n=671)						
Health facility (n=568)	84.7	84.2	85.7	93.6	0.362	0.824
Home (n=103)	15.4	15.9	14.3	6.5		
Household Characteristics						
Household head Age (n=668)						
15-34 (n=74)	11.1	10.8	21.4	6.5		
35-49 (n=283)	42.4	41.7	50.0	48.4	0.191	0.076
50+ years (n=311)	46.6	47.5	28.6	45.2		
Household head Sex (n=668)						
Male (n=435)	65.1	66.2	50.0	58.1	0.150	0.078
Female (n=233)	34.9	33.8	50.0	41.9		
Household head Education (n=603)						
None (n=248)	41.7	41.8	40.0	28.0		
Some education < completed secondary (n=276)	45.9	45.6	52.0	44.0	0.187	0.722
Secondary & Tertiary (n=79)	12.5	12.7	8.0	28.0		
Relationship to child (n=663)						
Parent (n=283)	42.7	42.9	50.0	32.3		
Grandparent (n=297)	44.8	44.7	42.9	48.4	0.546	0.623
Other (n=83)	12.5	12.4	7.1	19.4		
Food Security (n=629)						
Enough (n=503)	80.0	79.2	78.6	96.7	0.064	0.940
Not enough (n=126)	20.0	20.8	21.4	3.3		
SES Tertiles (n=654)						
Most poor (n=218)	33.3	33.3	42.9	29.0		
Middle (n=218)	33.3	34.0	35.7	19.4	0.126	0.392
Least poor (n=218)	33.3	32.9	21.4	51.6		
Area of Residence						
Mainly South African village (n=621)	92.6	92.1	96.4	96.8	0.461	0.406
Mainly Mozambican village (n=50)	7.5	7.8	3.6	3.2		

The prevalence of stunting was 18% in this age group (n=117), but though higher in HIV positive children (29%) than HIV negative children (18%), the difference did not reach statistical significance (p=0.136). Prevalence of underweight was 10% (n=67), while that of wasting was 7% (n=44). There was also no significant difference in the levels of underweight and wasting by HIV status (p=0.480 and p=0.389, respectively). (Figure 1).

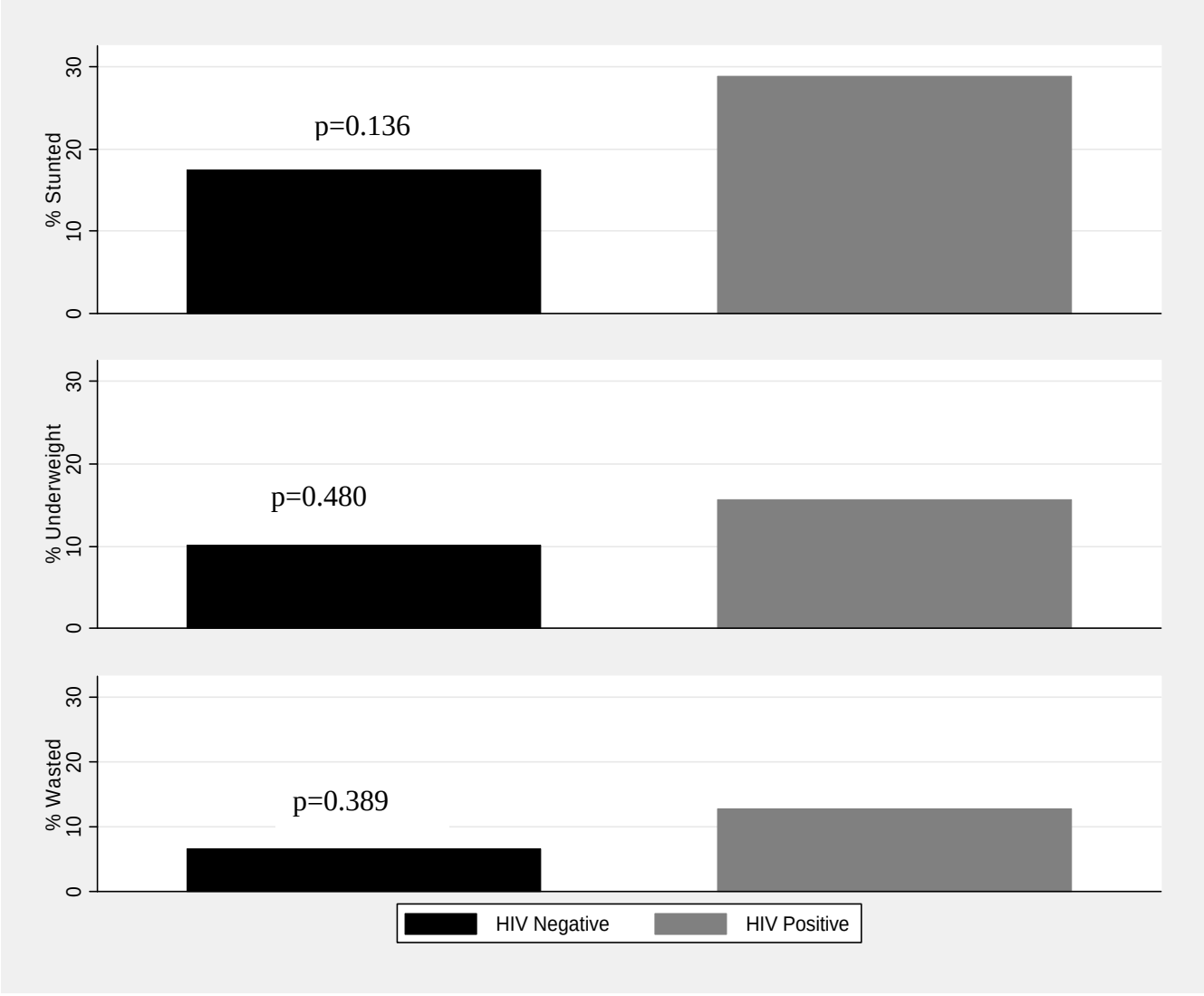

Figure 1: Prevalence of stunting, underweight and wasting for children aged 12-59 months by HIV status (n=671), Agincourt, South Africa (2007)

Impact of HIV status on nutritional outcomes at community level

The difference in nutritional outcomes between total sample (including HIV negative and HIV positive children and those not tested) and HIV free sample (excluding HIV positive children and those not tested) was insignificant. Mean height-for-age z-scores for total sample was -0.96 (SD; 1.18); while that of HIV free population was -0.95 (SD; 1.20) (p= 0.813); i.e. the means of the total sample and the HIV free sample were both about one standard deviation below the mean of the reference population. Mean weight-for-age z-scores for total sample was -0.54 (SD; 1.17) while that of HIV free population was -0.52 (SD; 1.16) (p=0.807). Mean weight-for-height z-scores for total sample was -0.05 (SD; 1.35) while that of HIV free population was -0.04 (SD; 1.34) (p= 0.891). Prevalence of stunting, underweight and wasting for total population was the same as that for HIV free population so no tests for difference of the proportions were done.

Determinants of child nutritional status

Results of regression analysis are shown on tables 2, 3 and 4. Only variables that were significantly associated with nutritional status from the univariate analyses at the 10% level of significance are included in the tables.

Height- and weight-for-age and weight-for-height z-scores

Key determinants of HAZ were at child level: HIV status, child's age and birth weight; and at maternal level: mother's age (all p<0.050). HIV positive children had significantly lower HAZ than HIV negative children (p=0.001); age was positively associated with HAZ (p<0.001); low birth weight was negatively associated with HAZ (p<0.001); while children of mother's aged 15-24 years had significantly lower HAZ than of mothers aged 25-34 years (p=0.005) (Table 2). Key determinants of WAZ were at child level: HIV status and birth weight; at maternal level: mother's age; and at household level: household head's age (all p<0.050). HIV positive children had significantly lower WAZ than HIV-negative children (p=0.001); birth-weight was positively

associated with WAZ ($p<0.001$); children of mother's aged 15-24 years had significantly lower WAZ than of mothers aged 25-34 years ($p=0.011$); while children of household heads younger than 35 years had lower z-scores compared to those of household heads in the age-category 35-49 years ($p=0.047$) (Table 3). Key determinants of WHZ were only at child level and included child's age and birth weight. Age was negatively associated with WHZ while birth-weight was positively associated with WHZ ($p=0$ .001 & $p<0.001$, respectively). (Table 4)

Stunting, underweight and wasting

Key determinants of stunting included child's age, and area of residence. Age was negatively associated with stunting ($p<0.001$); while children living in villages mainly inhabited by people of Mozambican origin had more than two-fold higher odds of being stunted ($p=0.024$). Association of stunting with mother's age was borderline ($p=0.051$), with children born to mothers younger than 25 years having a 1.6 higher odds of being stunted than children born to older mothers aged 35-49 years (Table 2). Only low birth weight was a significant predictor of underweight: children with low birth weight had three-fold higher odds of being underweight than other children ($p=0.002$)

(Table 3). No factor was significantly associated with wasting (Table 4).

Table 2: Regression analysis of determinants of HAZ and Stunting for children aged 12-59 months (n=671), Agincourt, South Africa (2007)

	HAZ[n=670]		Stunting[n stunted=117]	
	Univariate	**Multivariate[1]**	**Univariate**	**Multivariate[1]**
	Coeff [95% CI] P	Coeff [95% CI] P	OR [95% CI] P	OR [95% CI] P
Intercept		-1.5 [-1.9, -1.1] <0.001		
Child Characteristics				
HIV status (n=671)				
Negative (n=612) (ref)	0	0	1	1
Positive (n=28)	-0.7[-1.1, -0.2] 0.004	**-0.8[-1.2, -0.3] 0.001**	1.9 [0.8, 4.4] 0.142	2.3 [0.9, 5.6] 0.075
Unknown status (n=31)	0.3 [-0.2, 0.7] 0.249	0.2 [-0.2, 0.6] 0.398	0.3 [0.1, 1.4] 0.128	0.4 [0.1, 1.6] 0.186
Child age (n=671)	0.2 [0.2, 0.3] <0.001	**0.2 [0.1, 0.3] <0.001**	0.6 [0.5, 0.7]<0.001	**0.6 [0.5, 0.7]<0.001**
Birth weight (n=522)				
Normal; =2.5 kg (n=468) (ref)	0	0	1	1
Low; <2.5 kg (n=54)	-0.6[-0.9, -0.3]<0.001	**-0.6 [-0.9, -0.3]<0.001**	2.1 [1.1, 4.0] 0.023	1.9 [0.9, 3.8] 0.070
Maternal Characteristics				
Mother's age (n=659)				
25-34 (n=277) (ref)	0	0	1	1
15-24 (n=207)	-0.4 [-0.6, -0.2] 0.001	**-0.3 [-0.5, -0.1] 0.005**	1.7 [1.1, 2.7] 0.025	1.6 [1.0, 2.6] 0.051
35+ (n=175)	0.0 [-0.2, 0.2] 0.955	-0.1 [-0.3, 0.2] 0.578	0.8 [0.5, 1.4] 0.501	1.1 [0.6, 1.9] 0.851
Mother's Education (n=625)				
None (n=83) (ref)				
Education <Completed Secondary (n=381)	0.02 [-0.3, 0.3] 0.875	0.0 [-0.2, 0.3] 0.753		
Secondary & Tertiary (n=191)	0.3 [0.0, 0.7] 0.035	0.2 [-0.1, 0.5] 0.212		
Mother co-residence (n=671)				
Co-residing (n=650) (ref)	0	0		
Not co-residing (n=21)	0.6 [0.1, 1.1] 0.019	0.6 [-0.1, 1.2] 0.082		
Household Characteristics				
Relationship to child (n=663)				
Parent (n=283) (ref)	0	0		
Grandparent (n=297)	-0.0 [-0.2, 0.2] 0.892	0.1 [-0.2, 0.3] 0.503		
Other (n=83)	-0.3 [-0.6, 0.0] 0.057	-0.2 [-0.5, 0.1] 0.267		
Area of Residence (n=671)				
Mainly South African Village (n=621) (ref)	0	0	1	1
Mainly Mozambican Village (n=50)	-0.5 [-0.8, -0.1] 0.008	-0.3 [-0.7, -0.0] 0.062	2.4 [1.3, 4.6] 0.006	**2.2 [1.1, 4.3] 0.024**
R-squared		0.13		

1Only independent variables significantly associated with the outcome variable of interest at the 10% level of significance in the univariate analysis were included in multivariate analysis. Other independent factors examined include child's sex; place of delivery; nationality, and marital/union status of the mother; age, sex and highest education level of household head; household food security; and socio-economic status.

Table 3: Regression analysis of determinants of WAZ and Underweight for children aged 12-59 months (n=671), Agincourt, South Africa (2007)

	WAZ [n=671]		Underweight [n underweight= 67]	
	Univariate	**Multivariate[1]**	**Univariate**	**Multivariate[1]**
	Coeff [95% CI] P	Coeff [95% CI] P	OR [95% CI] P	OR [95% CI] P
Intercept		0.7 [-2.2, -0.3] 0.001		
Child Characteristics				
HIV status (n=671)				
Negative (n=612) (ref)	0	0	1	1
Positive (n=28)	-0.7 [-1.2, -0.3] 0.001	**-0.7 [-1.2, -0.3] 0.001**	1.5 [0.5, 4.4] 0.482	1.5 [0.5, 4.4] 0.512
Unknown status (n=31)	0.3 [-0.1, 0.7] 0.137	0.2 [-0.2, 0.6] 0.137	0.3 [0.0, 2.2] 0.235	0.3 [0.0, 2.2] 0.228
Birth weight (n=522)				
Normal; =2.5 kg (n=468) (ref)	0	0	1	1
Low; <2.5 kg (n=54)	-0.8 [-0.1, -0.5] <0.001	**-0.7 [-1.1, -0.4] <0.001**	3.1 [1.5, 6.5] 0.002	**3.1 [1.5, 6.4] 0.002**
Maternal Characteristics				
Mother's age (n=659)				
25-34 (n=277) (ref)	0	0		
15-24 (n=207)	-0.2 [-0.4, -0.0] 0.044	**-0.3 [-0.5, -0.1] 0.011**		
35+ (n=175)	0.0 [-0.2, 0.2] 0.979	-0.1 [-0.3, 0.2] 0.633		
Mother's Education (n=625)				
None (n=83) (ref)	0	0		
Education <completed secondary (n=381)	0.2 [-0.1, 0.4] 0.267	0.2 [-0.1, 0.5] 0.269		
Secondary & Tertiary (n=191)	0.4 [0.1, 0.8] 0.007	0.3 [-0.0, 0.6] 0.085		
Delivery place (n=671)				
Health facility (n=568) (ref)	0	0		
Home (n=103)	-0.3 [-0.5, -0.1] 0.019	-0.2 [-0.5, -0.1] 0.284		
Household Characteristics				
Household head Age (n=668)				
35-49 (n=283) (ref)	0	0		
15-34 (n=74)	-0.4 [-0.7, -0.1] 0.022	-0.3 [-0.6, -0.0] 0.047		
50+ years (n=311)	-0.2 [-0.3, 0.0] 0.124	-0.1 [-0.3, 0.7] 0.228		
SES Tertiles (n=654)				
Most poor (n=218) (ref)	0	0		
Middle (n=218)	0.2 [-0.1, 0.4] 0.172	0.0 [-0.2, 0.3] 0.690		
Least poor (n=218)	0.3 [0.1, 0.5] 0.012	0.1 [-0.1, 0.3] 0.500		
Area of Residence (n=671)				
Mainly South African Village (n=621) (ref)	0	0	1	1
Mainly Mozambican Village (n=50)	-0.5 [-0.8, -0.1] 0.006	-0.3 [-0.7, 0.0] 0.079	2.1 [1.0, 4.6] 0.054	2.0 [0.9, 4.4] 0.094
R-Squared		0.09		

1Only independent variables significantly associated with the outcome variable of interest at the 10% level of significance in the univariate analysis were included in multivariate analysis. Other independent factors examined include child's sex and age; child's relationship to household head; nationality, and marital/union status of the mother; mother's co-residence with child; sex and highest education level of household head; and household food security

Table 4: Regression analysis of determinants of WHZ and wasting for children aged 12-59 months (n=671), Agincourt, South Africa (2007)

	WHZ [n=670]		Wasting [n wasted = 44]	
	Univariate	**Multivariate[1]**	**Univariate**	**Multivariate[1]**
	Coeff [95% CI] P	Coeff [95% CI] P	OR [95% CI] P	OR [95% CI] P
Intercept		0.5 [0.0, 0.9] 0.034		
Child Characteristics				
HIV status (n=671)				
Negative (n=612) (ref)	0	0	1	1
Positive (n=28)	-0.5 [-1.0, -0.0] 0.047	-0.5 [-1.0, 0.1] 0.094	1.7 [0.5, 5.9] 0.395	1.9 [0.5, 6.5] 0.333
Unknown status (n=31)	0.2 [-0.3, -0.1] 0.322	0.2 [-0.3, 0.7] 0.338	0.48 [0.1, 3.6] 0.471	0.5 [0.07, 4.1] 0.560
Child age (n=671)	-0.2 [-0.3, -0.1] 0.001	**-0.2 [-0.3, -0.1] 0.001**		
Birth weight (n=522)				
Normal; =2.5 kg (n=468) (ref)	0	0		
Low; <2.5 kg (n=54)	-0.7 [-1.1, -0.3]<0.001	**-0.7 [-1.0, -0.3]<0.001**		
Maternal Characteristics				
Mother's Education (n=625)				
None (n=83) (ref)	0	0		
Some education <completed secondary (n=381)	0.2 [-0.1, 0.5] 0.175	0.2 [-0.2, 0.5] 0.302		
Secondary & Tertiary (n=191)	0.3 [-0.0, 0.7] 0.081	0.2 [-0.2, 0.6] 0.300		
Delivery place (n=671)				
Health facility (n 568) (ref)	0	0	1	1
Home (n 103)	-0.4 [-0.7, -0.1] 0.010	-0.2 [-0.6, -0.1] 0.149	2.2 [1.1, 4.4] 0.027	2.0 [1.0, 4.1] 0.059
Household Characteristics				
Household head Age (n 668)				
35-49 (n 283) (ref)	0	0		
15-34 (n 74)	-0.4 [0.7, -0.0] 0.034	-0.3 [-0.7, -0.0] 0.066		
50 years (n 311)	-0.2 [-0.4, 0.0] 0.086	-0.2 [-0.4, -0.0] 0.088		
SES Tertiles (n 654)				
Most poor (n 218) (ref)	0	0		
Middle (n 218)	0.1 [-0.1, 0.4] 0.363	0.1 [-0.2, 0.3] 0.541		
Least poor (n 218)	0.3 [0.0, 0.5] 0.038	0.2 [-0.1, 0.4] 0.241		
Area of Residence (n 671)				
Mainly South African Village (n 621) (ref)			1	1
Mainly Mozambican Village (n 50)			2.6 [1.1, 6.1] 0.033	2.3 [0.9, 5.5] 0.070
R-squared		0.07		

1Only independent variables significantly associated with the outcome variable of interest at the 10% level of significance in the univariate analysis were included in multivariate analysis. Other independent factors examined include child's sex; child's relationship to household head; age, nationality and marital/union status of the mother; mother's co-residence with child; sex and highest education level of household head and household food security.

Table 4: Regression analysis of determinants of WHZ and wasting for children aged 12-59 months (n=671), Agincourt, South Africa (2007)

	WHZ [n=670]		Wasting [n wasted = 44]	
	Univariate	**Multivariate[1]**	**Univariate**	**Multivariate[1]**
	Coeff [95% CI] P	Coeff [95% CI] P	OR [95% CI] P	OR [95% CI] P
Intercept		0.5 [0.0, 0.9] 0.034		
Child Characteristics				
HIV status (n=671)				
Negative (n=612) (ref)	0	0	1	1
Positive (n=28)	-0.5 [-1.0, -0.0] 0.047	-0.5 [-1.0, 0.1] 0.094	1.7 [0.5, 5.9] 0.395	1.9 [0.5, 6.5] 0.333
Unknown status (n=31)	0.2 [-0.3, -0.1] 0.322	0.2 [-0.3, 0.7] 0.338	0.48 [0.1, 3.6] 0.471	0.5 [0.07, 4.1] 0.560
Child age (n=671)	-0.2 [-0.3, -0.1] 0.001	**-0.2 [-0.3, -0.1] 0.001**		
Birth weight (n=522)				
Normal; =2.5 kg (n=468) (ref)	0	0		
Low; <2.5 kg (n=54)	-0.7 [-1.1, -0.3]<0.001	**-0.7 [-1.0, -0.3]<0.001**		
Maternal Characteristics				
Mother's Education (n=625)				
None (n=83) (ref)	0	0		
Some education <completed secondary (n=381)	0.2 [-0.1, 0.5] 0.175	0.2 [-0.2, 0.5] 0.302		
Secondary & Tertiary (n=191)	0.3 [-0.0, 0.7] 0.081	0.2 [-0.2, 0.6] 0.300		
Delivery place (n=671)				
Health facility (n=568) (ref)	0	0	1	1
Home (n=103)	-0.4 [-0.7, -0.1] 0.010	-0.2 [-0.6, -0.1] 0.149	**2.2 [1.1, 4.4] 0.027**	2.0 [1.0, 4.1] 0.059
Household Characteristics				
Household head Age (n=668)				
35-49 (n=283) (ref)	0	0		
15-34 (n=74)	-0.4 [-0.7, -0.0] 0.034	-0.3 [-0.7, -0.0] 0.066		
50+ years (n=311)	-0.2 [-0.4, 0.0] 0.086	-0.2 [-0.4, -0.0] 0.088		
SES Tertiles (n=654)				
Most poor (n=218) (ref)	0	0		
Middle (n=218)	0.1 [-0.1, 0.4] 0.363	0.1 [-0.2, 0.3] 0.541		
Least poor (n=218)	0.3 [0.0, 0.5] 0.038	0.2 [-0.1, 0.4] 0.241		
Area of Residence (n=671)				
Mainly South African Village (n=621) (ref)			1	1
Mainly Mozambican Village (n=50)			2.6 [1.1, 6.1] 0.033	2.3 [0.9, 5.5] 0.070
R-squared		0.07		

1Only independent variables significantly associated with the outcome variable of interest at the 10% level of significance in the univariate analysis were included in multivariate analysis. Other independent factors examined include child's sex; child's relationship to household head; age, nationality and marital/union status of the mother; mother's co-residence with child; sex and highest education level of household head and household food security.

Summary of determinants

Key predictors of nutritional status in children aged 12-59 months in Agincourt include child's HIV status, child's age, birth weight, maternal age, age of household head, and area of residence. HIV status was strongly associated with z-scores but its association with stunting, underweight and wasting was not significant at 5% level of significance.

Discussion

This study has described the prevalence of HIV, nutritional outcomes by HIV status, and determinants of nutritional status among children 12-59 months living in rural South Africa. Nutritional status was determined using height- and weight-for-age and weight-for-height z-scores. HIV positive children had poorer nutritional outcomes compared to their HIV negative counterparts. In addition to HIV, important covariates of children's nutritional status at the child, household and community level were detected. At child level, these included child's age and birth weight; at maternal level, maternal age; at household level, age of household head; and at community level, area of residence.

The HIV prevalence in this study is seemingly low and is comparable to 2005 national estimates among children aged 2-4 years (5%) in South Africa [26], despite high HIV prevalence among women of child-bearing age [13]. Prevention of mother to child transmission (PMTCT) programs have been scaled up in South Africa in the last few years and some milestones have been achieved for example with regards to antenatal HIV testing and uptake of nevirapine for infected mothers [27]. This prevalence of HIV in children is however important both for individual wellbeing of the children and for public health purposes. HIV infection influences nutritional outcomes of infected children at an individual level [6], while malnutrition in HIV infected children leads to higher mortality [7]. HIV in children has been associated with remarkable demographic impacts in South Africa. Dorrington et al. (2006) estimated that 44% of mortality among children aged 0-14 years

was due to HIV despite only 2% of this age group being infected [28]. The higher prevalence of HIV observed in girls compared to boys cannot be fully explained in this study, but may result from longer survival of HIV positive girls. Although numbers are small, during a one year follow-up of HIV positive children, two boys died and no girls [29].

This study documents a high prevalence of undernutrition, particularly stunting, which is more prevalent in HIV positive children. The higher vulnerability of HIV positive children to poorer nutritional outcomes in this study may be influenced by their HIV status, since after controlling for other covariates of nutritional status in children, HIV status remained a significant determinant of many of the outcomes. Growth failure has been associated with HIV elsewhere in sub-Saharan Africa [7, 30] and in South Africa in particular [31]. In settings with unhygienic environments and poor water, infections in young children – particularly diarrhoea – are important causes of undernutrition [32]. Recurrent illnesses such as diarrhoea, exacerbated in HIV positive children due to lowered immunity, may play a major role in poor nutritional outcomes. This study also documented other vulnerabilities that may jeopardize the nutritional status of HIV positive children relative to their HIV negative counterparts. These include lower birth weight, lower maternal education and less likelihood of maternal co-residence with child mainly due to death.

Consistent with other studies in developing countries [10], child level factors including birth weight and child's age emerged as key. Though further investigations are needed to establish the causes of low birth weight in this setting, one factor may be maternal health and the impact of HIV exposure, as a third of women of childbearing age are HIV infected [13]. Maternal HIV infection which leads to higher rates of maternal opportunistic infections has particularly been associated with foetal growth retardation leading to smaller size and low birth weight [33]. Birth weight was lower in HIV positive children compared to their negative counterparts as also found in other studies in sub-Saharan Africa [34]. Child age was differentially related to nutritional status. With regards to

height-for-age z-scores and stunting, indicators for chronic malnutrition, older children had better outcomes, while with regards to weight-for-height z-scores, older children had poorer outcomes. The height-for-age z-scores and higher stunting in younger children may be associated with low birth weight, followed by catch up growth in the older years. The poorer outcomes related to weight-for-height z-scores in older children may be associated with weaning practices [35].

The maternal level factor found to be significantly associated with child's nutritional status was maternal age. Maternal age has been documented in other studies in the developing world as an important risk factor for child malnutrition [11]. The increased risk of malnutrition in children of younger mothers may relate to inexperience and inadequate child care, or to biological characteristics such as small maternal size with potential for low birth weight and later poor nutritional outcomes.

At the household level, only age of the household head emerged as a predictor of nutritional outcomes associated with both weight-for-age and weight-for-height z-scores. The pathway through which age of the household head may influence nutritional outcomes of the child could be through income and food security of the household. Contrary to expectation, food insecurity did not emerge as an important factor with regards to nutritional status of children in this age category. The lack of association found between food (in)security and nutritional outcomes may relate to food (in)security being a household-level measurement and thus less sensitive than individual-level measurements of child's food intake. Additionally, poor nutritional outcomes may not only be associated with the quantity of food but also the quality, which this study did not assess. Food variety and dietary diversity are limited in those living in poor socio-economic circumstances in South Africa and are associated with nutritional status of South African children [36]. Additionally, socio-economic status, a factor associated with nutritional outcomes in other studies in the developing world [37], was not a significant determinant of nutritional outcomes after controlling for other covariates. This

suggests that other factors may be more important in determining the nutritional status of young children in this community. Socio-economic status was estimated using a household asset index as a proxy measure of relative household wealth rather than actual income or expenditure levels, and may not necessarily relate to households' current socio-economic status. However, this method has been shown as valid elsewhere [21].

At the community level, area of residence emerged as a predictor of nutritional outcomes. Area of residence serves as a proxy for various factors at community level, including environmental factors, availability of health care and support services, and shared cultures. Children living in villages mainly inhabited by people of Mozambican origin had poorer nutritional outcomes. These villages served as refugee settlements during and after the civil war in Mozambique from the early to mid-1980s. Consequently, well over 90% of people living in these villages are of Mozambican origin, whereas they constitute about 30% of inhabitants over the study site as a whole. Though the situation is changing, people in these villages have lived with limited legal recognition without fully being integrated into South African society. The villages have poor dwellings and infrastructure and are worse off than mainly South African villages with respect to basic services including water, sanitation, electricity and health facilities [38, 39]. Other researchers in the study area have also found poorer health outcomes in children living in former Mozambican households [40]. While this study showed that being born to a mother of Mozambican origin does not disadvantage the child with regards to nutritional outcomes, previous work documented significantly higher mortality in children born to Mozambican mothers compared to those born to South African mothers [41]. Community interventions to improve living conditions could contribute to better health and nutritional outcomes in children.

This study has demonstrated HIV status as an important independent modifiable risk factor for poor nutritional status of children. It raises the question as to the extent community-based nutritional

assessments will be affected by HIV positive children in the community. Our study finds no significant impact of HIV status on the nutritional status of children in the community overall. Given the difficulties of HIV testing at community level, both technical and ethical, this study concludes that there is insufficient evidence to recommend aggressive HIV screening of children during community nutritional assessments in settings with similar or lower levels of HIV prevalence in children.

A few limitations of this study are important to note. The sample for the 2007 growth survey was drawn from the existing Agincourt HDSS. The time lag between data collection for the Agincourt HDSS sampling frame and data collection for the growth survey meant that infants under one year of age were not included. This limitation may have lowered the proportion of children with HIV infection reported in our study, and masked the extent of poor nutritional outcomes in HIV positive children as the most vulnerable children may have died by their first birthday [42]. Further, the bivariate results by HIV status should be interpreted with caution as the small proportion of HIV positive children in our study may bias the strength of the associations. A further limitation relates to the HIV tests employed: according to WHO recommendations, antibody tests are appropriate for HIV screening in children aged 18 months and above. As maternal antibodies may still be present in younger children, assays to detect the virus rather than antibodies are recommended for children younger than 18 months [25]. However, most uninfected HIV-exposed children have lost maternal antibodies by 12 months of age; hence an HIV antibody-positive test at this age may thus be considered indicative of HIV infection [25, 43]. Since only three children under 18 months of age tested HIV positive in our study, the likelihood of maternal antibodies affecting the results is low.

Despite these limitations, findings reinforce the need to focus on the nutritional status of all young children in rural communities, including those infected or exposed to HIV. Effective maternal interventions on nutrition and care of young children are needed. Further, the higher risk of poor

nutritional outcomes in children with very young mothers indicates need for community- and school-based education to reduce early pregnancies, and post-school training and job opportunities particularly for girls. We further recommend interventions targeting development of more disadvantaged areas, including improved provision of basic services such as water and sanitation, electricity and other basic infrastructure. Additionally, improved legal and social integration of people of Mozambican origin for example through accelerated provision of identity documents for those who lack these may improve the nutritional status of their children through prompt access to government social grants such as child support grants.

Interventions to improve nutritional outcomes of children infected or exposed to HIV may include improving access to and utilisation of PMTCT services and targeted paediatric HIV screening and support to infected children. Despite scale-up of PMTCT programs in South Africa in the last few years [27], access to and utilisation of these services remain a challenge particularly in rural areas [44, 45] and are in urgent need of improvement. Where PMTCT has failed, early detection of HIV positive children is critical for appropriate medical management, reduction of morbidity and mortality and improvement of quality of life [25]. The high level of paediatric HIV test uptake in the study indicates that rapid tests for HIV screening in children are acceptable in this rural community. Further, in a one year qualitative follow-up study, most caregivers of HIV positive children reported a positive response to knowing the child's status [29]. This knowledge was said to heighten caregiver's own competency in caregiving and health care seeking [29]. Based on these findings, the negative impact of HIV on the growth of infected children [7, 30], and the estimated high impact of HIV infection on child mortality [28], we recommend paediatric HIV screening at community level for those exposed to HIV or suspected to be at risk for HIV. This may be done using rapid tests with appropriate follow-up measures in the presence of HIV antibodies including definitive testing and support to the mother/caregiver and her family including counselling [25].

Interventions targeted specifically at HIV positive children could include food supplementation [30] and antiretroviral treatment [46].

Conclusion

This study documents poor nutritional status among children aged 12-59 months and heightened nutritional vulnerability in HIV positive children compared to their HIV negative counterparts. Early paediatric HIV testing of exposed or at risk children, followed by appropriate medical care including antiretroviral treatment and nutritional supplementation to infected children may improve their nutritional status. However, there is insufficient data to recommend aggressive HIV screening during community-based nutritional assessments. In addition to HIV status, other child, maternal and community-level characteristics emerge as strong determinants of nutritional outcomes in these children. Interventions that effectively counter malnutrition are paramount if we are to address the sequelae of poor child nutrition: poor cognitive development, reduced human capital, premature mortality and other health consequences [2-4].

List of Abbreviations

HDSS	Health and socio-demographic surveillance system
AIDS	Acquired immune deficiency syndrome
ANOVA	Analysis of variance
ART	Anti-retroviral therapy/treatment
CI	Confidence interval
HAZ	Height-for-age z-scores
HIV	Human immunodeficiency virus
Kg	Kilogram
MDGs	Millennium development goals
P	Probability
PMTCT	Prevention of mother to child transmission of HIV
OR	Odds ratio
SD	Standard deviation
SES	Socio-economic status
USD	United States dollar
WAZ	Weight-for-age z-scores
WHO	World Health Organization
WHZ	Weight-for-height z-scores

Authors' Contributions

EWK-M: Design of the study, project implementation and management, data management and analysis, writing of the manuscript and approval for submission

KK: Design of the study, overall project co-ordination, review of the manuscript and approval for submission

JMP: Design of the study, review of the manuscript and approval for submission

SMT: Design of the study, review of the manuscript and approval for submission

KK-G: Analytic guidance, review of the manuscript and approval for submission

DD: Design of the study, review of the manuscript and approval for submission

FXG: Project implementation and management, review of the manuscript and approval for submission.

SAN: Design of the study, overall project management, review of the manuscript and approval for submission

Acknowledgements

We acknowledge funding from the National Research Foundation (NRF) and the Medical Research Council (MRC). The Agincourt health and socio-demographic surveillance system, is funded by the Wellcome Trust, UK (Grant nos. 058893/Z/99/A and 069683/Z/02/Z) with support from the William and Flora Hewlett Foundation, USA. It is also a member of the INDEPTH Network. Elizabeth Kimani-Murage has a PhD fellowship funded by the William and Flora Hewlett Foundation, USA, while Dr. Shane Norris is on a Wellcome Trust funded research fellowship. We acknowledge the management and data collection teams at the MRC/Wits Rural Public Health and Health Transitions Research Unit (Agincourt); the training and data-entry teams from the Birth-To-Twenty Programme, University of the Witwatersrand, South Africa, funded by the Wellcome Trust, UK (077210/Z/05/Z); and the African Population and Health Research Center, Nairobi, Kenya during preparation of this manuscript. We acknowledge Mark Collinson for his technical contribution during design of the study, and Professor Haroon Saloojee for his critical comments.

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Paper III

Kimani-Murage EW, Manderson L, Norris SA, Kahn K. 'You opened our eyes': care-giving after learning a child's positive HIV status in rural South Africa. Health and Social Care in the Community (2010) 18(3), 264–271.

Permission to attach it to the thesis granted.

Conference Proceedings

I. Kimani-Murage E.W, Manderson L, Norris S.A., Kahn K. “You opened our eyes”: Caregiving after learning a child’s positive HIV status in rural South Africa. Oral presentation at the INDEPTH AGM, 26-29th October, 2009, Pune, India.

II. Kimani-Murage EW, Manderson L, Norris SA, Kahn K. “You opened our eyes”: Caregiving after learning a child’s positive HIV status in rural South Africa. Oral presentation at the Population Association of Southern Africa (PASA) conference, 8-10th July 2009, Cape Town, South Africa.

Health and Social Care in the community

Health and Social Care in the Community (2009) doi: 10.1111/j.1365-2524.2009.00891.x

'You opened our eyes': care-giving after learning a child's positive HIV status in rural South Africa

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Abstract

Caregivers of young children identified as HIV positive, residing in Agincourt, rural South Africa were advised of their child's status. How was this knowledge received, and how did it influence care-giving and support? Interviews were conducted in May to June 2008 with caregivers of HIV positive children aged 1–5 years, 1 year following the child's HIV test and disclosure of status. Drawing on data from 31 semi-structured questionnaires and 21 in-depth interviews, we describe caregivers' attitudes, reactions, fears and aspirations after learning a child's HIV status, the perceived usefulness of the knowledge, barriers to care-giving and support received. Sociodemographic data collected through the questionnaire were analysed using Stata. Qualitative data were coded in NVIVO 8 and analysed inductively to identify themes and their repetitions and variations. Although almost half of the caregivers responded negatively initially, 1 year later, almost all had accepted and valued knowing their child's HIV status as this had enhanced their competency in care-giving. Counselling from health providers and personal spirituality helped caregivers to accept the child's status and cope with its implications. Most caregivers had high aspirations for the child's future, despite some expressed difficulties associated with care-giving, including financial constraints, information gaps and barriers to healthcare. The results indicate an opportunity for paediatric HIV screening in communities with high HIV prevalence. This would facilitate early uptake of available interventions, so enhancing the survival of HIV positive children.

Keywords: attitudes, care-giving, child health, HIV/AIDS, paediatric care, qualitative research

Accepted for publication 27 August 2009

Introduction

The Millennium Development Goal 4 to reduce mortality of children under 5 years is compromised in sub-Saharan Africa by HIV/AIDS (Garenne and Gakusi 2006). Without anti-retroviral therapy (ART), half of HIV-infected children will die before their second birthday (Brahmbhatt et al. 2006). In South Africa, where one third of pregnant women attending public antenatal clinics are infected (Department of Health 2008), the prevalence of HIV among children aged 2–4 years is estimated at 5% (Shisana et al. 2008), and HIV-related mortality of children aged less than 15 years is estimated at 42% (Dorrington et al. 2004). While the prevention of mother to child transmission (PMTCT) is an efficient and cost-effective way to tackle paediatric HIV, availability of, access

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to and utilisation of PMTCT programmes in public facilities are limited, and many children continue to be infected with and die from HIV/AIDS (Doherty et al. 2003, Dorrington et al. 2004, Department of Health 2008). This underscores the need for early paediatric HIV diagnosis and timely interventions such as proper counselling of caregivers, ART, and social and nutritional support (Krabbendam et al. 1998, Verweel et al. 2002, Villamor et al. 2002).

Childcare behaviours including feeding, hygiene practices, health-seeking behaviours and psychosocial stimulation are integral to the growth, development and survival of children (UNICEF 1990, Engle et al. 1999). These practices may even be more fundamental for HIV positive children. Studies of child rearing practices of HIV positive children, conducted from 1990 and 2000, indicate that attitudes of caregivers are mixed (Klunklin and Harrigan 2002). Conceptualisation of HIV as 'social and physical death' may hinder constructive use of knowledge of HIV status (Meursing and Sibindi 2000). Care-giving may be influenced by social stigmatisation, financial limitations and emotional strain (Brouwer et al. 2000, Klunklin and Harrigan 2002). However, the literature on the usefulness of paediatric HIV testing and disclosure is limited, and the need for context specific evidence remains.

Between April and August 2007, following obtaining written informed consent, voluntary HIV testing and caregiver counselling were undertaken for children aged 1–5 years, randomly selected, in Agincourt, rural South Africa. Two rapid HIV tests – Uni-Gold™ (Trinity Biotech, Bray, Ireland) and Determine™ (Abbott, Wiesbaden, Germany) – were conducted concurrently. The HIV testing and disclosure was voluntary as it was undertaken in the context of a research rather than a therapeutic context. Hence, results were disclosed to the child's caregiver if they wished to know the status. A child was defined as HIV negative if both tests were negative, HIV positive if both tests were positive and indeterminate if test results were discordant. Children determined positive and those with indeterminate results were referred to health facilities in the community for confirmatory tests, further counselling and advice. In total, 880 test attempts were made of which 841 (96%) consented. All but two respondents received the test results: one did not want to know and the other one could not await the results due to other commitments. In total, 35 (4.2%) children tested HIV positive and one had indeterminate results.

The caregivers of those children identified as HIV positive were followed-up a year later. In this study, we describe their attitudes, reactions, fears and aspirations following learning of a child's HIV status, and the perceived usefulness of this knowledge to care-giving. We also describe the limitations faced by and support provided to the caregivers.

Study setting and population

The research was conducted in rural northeast South Africa, in the Agincourt subdistrict of Mpumalanga Province, bordering with Mozambique, described elsewhere (Tollman et al. 1999, Kahn et al. 2007). The study was undertaken within the Agincourt health and sociodemographic surveillance system (AHDSS) framework, which since 1992 has followed some 70 000 people living in 11 700 households in 21 contiguous villages. The population comprises Tsonga-speaking people, including former refugees from Mozambique now settled in the area and labour migrants travelling to and from other parts of South Africa (Collinson et al. 2006, Collinson et al. 2007). Income levels are low and unemployment levels high (40–50%) (Development Bank of Southern Africa 1993). A network of five primary care clinics refer patients to a larger public health centre in the community, 25 km from the nearest district hospital. About a third of pregnant women visiting public health clinics in the area are HIV positive (Department of Health 2008).

Methods

Between May and June 2008, all children (2–6 years) identified as HIV positive the previous year (n = 35; 12 boys and 23 girls) were followed-up. For analysis and documentation purposes, their ages were truncated to whole completed years; thus, a child documented as 2 years would be between 2 years 0 months and 2 years 11 months.

A semi-structured questionnaire was administered to all caregivers (n = 31), and in-depth interviews conducted with those caregivers aware of the child's positive HIV status (n = 22). Caregiver in this study refers to child's primary caregiver, either biological mother or other carer (e.g. grandmother or other relative). The questionnaire included open-ended questions on child's health status, health seeking, feeding and sociodemographic details of the caregiver. Issues explored in the in-depth interviews included attitudes and reactions to knowing HIV status of the child, the impact of this on caring for the child, antiretroviral (ARV) treatment seeking for the child, views on treatment and services in the community for HIV positive children, challenges in caregiving and support networks for caregivers.

The questionnaire was administered first, with an appointment made for an in-depth interview on a different day. Daily debriefing sessions were held between the principal researcher (first author) and the fieldworkers to discuss issues and themes emerging from the interviews and to ensure consistency of meaning to questions. New issues and emerging themes were explored in subsequent interviews. Both the questionnaire and in-depth

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interview guide were backtranslated by first-language Tsonga speakers from English to Tsaonga then retranslated back to English by an independent person. The backtranslation enabled the principal researcher, who was not Tsonga-speaking, to ensure that meaning to questions was not lost in the translation. Interviews were conducted in Tsonga, and were tape-recorded. Two respondents refused tape-recording, but neither was aware of the child's HIV status and so only responded to the questionnaire. The questionnaire took about 20–30 minutes to complete while in-depth interviews took about 45 minutes to 1.5 hours.

Fieldwork was conducted by three fieldworkers, one female, two males, whose first language was Tsonga and were residents of the study area. They were well trained on qualitative data collection and on the specific study before beginning of fieldwork. Role plays followed by pilot interviews ensured clear understanding of questions. Although the principal investigator was not a Tsonga speaker and could not conduct interviews, she accompanied the research assistants in the field throughout the data collection period. Transcription and translation of interviews were also done by a local first-language Tsonga speaker. When in doubt, the translator consulted with the other fieldworkers. A third party was consulted by the principal researcher in instances where it was not fully clear.

Ethical approval for the study was granted by the University of the Witwatersrand Committee for Research on Human Subjects (Medical). Written informed consent was obtained from each caregiver before data collection for the questionnaire and the in-depth interview separately. Health facilities and home-based care groups were mobilised at the beginning of the study through letters and meetings with the investigators to ensure availability of care and assistance for HIV positive children and their caregivers.

Sociodemographic data collected from the questionnaire were analysed using Stata version 10.0 (StataCorp LP, College Station, TX, USA). Interview text analysis was inductive. Themes were developed from literature and from women's narratives. Preliminary analysis occurred concurrently with the continued administration of interviews to identify emergent themes to pursue in subsequent interviews (Guest et al. 2006). Transcribed word files were imported into NVIVO 8 software (QSR International Pty Ltd, Doncaster, Victoria, Australia). Primary coding of the transcripts was undertaken by the first author; following this, meta-codes and primary themes were identified, with attention to contradiction and diversity of experience and attitudes. Authors then discussed these findings to ensure consistency of understandings and interpretation. Analysis across all transcripts was conducted using a constant comparative method to identify themes and their repetitions and variations (Strauss and Corbin 1990, Ryan and Bernard 2003).

Results

Of the 35 children determined positive in 2007, two had died prior to this study, one was away with the mother and one caregiver refused to participate. Therefore, 31 caregivers – 8 (26%) boys and 23 (74%) girls – participated in 2008 (all nonparticipants were boys).

The mean age of the children was 4.6 years (SD 1.5); that of the caregivers was 33.3 years (SD 9.8). All caregivers were women, predominantly the biological mother (24 children 77%). Twenty-five children (81%) co-resided with the biological mother; only two (6%) lived in the same household as their father. Reasons for mother not co-residing with the child included death (4, 13%) and living elsewhere following marriage (2, 6%). Fathers did not co-reside with the child due to death (8, 26%), labour migration (13, 42%), or living elsewhere because he was never married to, or was divorced or separated from the mother (8, 26%). Eleven (36%) caregivers had little or no formal education, and only three caregivers worked outside the home (Table 1).

Twenty-four caregivers (77%) knew the child's HIV status, three of whom already knew before the 2007 growth study. Two mothers and five nonmaternal caregivers did not know the child's status: for mothers because results were not disclosed to them and for nonmaternal caregivers because they had taken on caregiving after the 2007 study for reasons including death of the mother. Twenty-two caregivers participated in in-depth interviews; two refused after responding to the questionnaire; one interview was erroneously not recorded. The narratives presented are therefore based on 21 in-depth interviews, of which 19 were with mothers. Information from open-ended questions in the questionnaires was used to supplement information from in-depth interviews.

Knowing the child's HIV status

Caregivers were asked to recall their reactions and attitudes to knowing a child's HIV status immediately after the test, and to describe their current attitudes. Most caregivers (19, 90%) indicated that they had accepted the results. While more than half (12) reported accepting the results immediately, a third reported initial reactions such as anxiety, fear, disbelief, surprise, worry and denial. Counselling by health professionals helped the women to cope: 'I was frightened, then I went for counselling, then I was fine and free' (mother, 33 years). So did spiritual beliefs – 'it is what God has wanted it to be'

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Table 1 Background characteristics of study participants, Agincourt subdistrict, South Africa, 2008

Child's characteristics	Number (%)/Mean (SD, Range)
Number	31
Mean age in years	4.6 (SD 1.5, range 2–6)
Sex	
Boys	8 (26%)
Girls	23 (74%)
Caregiver's characteristics	
Relationship with caregiver	
Mother	24 (77%)
Grandmother	4 (13%)
Other relative	3 (10%)
Caregiver's mean age in years	33.3 (SD 9.8, range 18–61)
Mother	32.6 (SD 6.4, range 25–50)
Grandmother	59.0 (SD 2.8, range 57–61)
Other relative	22.0 (SD 4, range 18–26)
Education level of caregiver	
No formal education	11 (36%)
Some primary and completed primary	5 (16%)
Post primary	15 (48%)
Occupation of caregiver	
Working (formal and self-employment)	3 (10%)
Not working	27 (87%)
Studying	1 (3%)
Parental co-residence and survivorship	
Co-residing with mother	25 (81%)
Co-residing with father	2 (6%)
Mother dead	4 (13%)
Father dead	8 (26%)

(mother, 25 years), fate or lack of alternatives – 'If I don't accept it, there is nothing I can *do*' (mother, 39 years). Social support after disclosure to others, and self-consolation or positive attitudes were also important: 'it is an illness which affects anyone in the world, even a president or a nurse, everyone can be affected' (mother, 34 years). The two women who rejected the results in 2007 still refused to accept the child's status 1 year later.

Caregivers expressed great aspirations for their children in terms of their health, ability to grow and live like other children, go to school, be cured, and grow up to assume adult responsibilities like getting employment. Thirteen respondents (62%) expressed no particular fear currently or with regard to the child's future; others feared early death, poor health compromised when the caregiver was financially constrained, and infection of others from body fluids. These fears were somewhat counteracted by expressions of hope for a cure.

Knowledge of child's HIV status could lead to favour or discrimination against the child, but extreme reactions were uncommon. Caregivers felt that children should be treated the same regardless of their HIV status, and there was no indication of differential treatment in terms of general care, feeding and health seeking. Occasionally, caregivers gave priority to healthcare to a child with HIV when she or he was ill, assuming that they had less resistance to infection than other children. In few instances, too, there was an indication of going to extremes to please the child 'I try to borrow from somewhere to make her happy' (Sister, 26 years).

Caring for the HIV-infected child

Caregivers emphasised that knowing the child's HIV status led to helpful advice from health professionals and other people such as relatives. Most respondents (95%) felt that knowing the HIV status of the child enhanced their competency in care-giving. Sixteen respondents (76%) received advice regarding child's illnesses and ART; seven (33%) regarding nutrition, and seven (33%) regarding hygienic practices and protecting other children from infection. Caregivers expressed faith in advice from health professionals 'If they tell you at the Hospital that it is good, it is good' (Mother, 42 years).

Hygiene and health-care seeking

Although several respondents maintained that their children led 'normal' lives like other children, and a few indicated that the children rarely got sick, most caregivers reported frequent flu, sores and other illnesses, although such illness was not debilitating: 'She is so active and plays very well. Even when she's got flu or diarrhoea, she copes very well with it' (grandmother, 57 years). Sometimes these illnesses spread to other children in the household. One mother, 33 years, reported that all her children live with sores and she could not distinguish if they were HIV-related or not. The poor health status of the children indicates need for adequate attention to hygiene and health-care seeking, and caregivers noted that knowing the child's status awakened their knowledge in this area:

> Your visit opened our minds; we should not think that it is flu only while it is not… I found happiness this year. Last year I knew, I opened my mind, I took steps…If you had not come to tell us I would have been lost… (what I have learnt is that) if she plays she must play where it is safe, if she coughs she must not infect other children, and if she gets injured she should not touch another child…I cover her sores, so that she doesn't infect other children (mother, 29 years).

Knowing the child's HIV status gave others an understanding of the importance of seeking ART when indicated. Three children were on ART at the time of the study. Eight other women had sought ART but the chil-

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dren had not been placed on medication for medical and caregiver reasons: according to health professionals, the child's immune system was still sufficiently strong, they were awaiting test results before a decision could be made, the child was too young for ART; or the caregiver lacked transport money to collect the drugs. Two caregivers whose children were on ART reported that the child's health had consequently improved; one was still waiting to assess the effects of treatment.

Child feeding

Caregivers had limited knowledge of feeding practices prior to learning about the child's status, and advice from health professional facilitated changes in feeding:

I now know the illness that she has; what those who know it call it, they opened my eyes. You who are educated, you open our eyes…I know that I must buy meat and rice. In the past I only knew that they have to eat African herbs. I didn't know that even bread and butter helps. I didn't know that spinach helps; we were just eating. (mother, 42 years)

There are things we were not giving the child though the child was supposed to get. They (health professionals) told us about fruits, vegetables, exercise. (sister, 26 years)

Limitations in care-giving and support networks

Although caregivers were determined to provide the best care for their children so that they could have a better life, they faced financial barriers, poor access to health services, and compromised physical ability to care due to their own poor health. Caregivers often linked financial limitations to not having a job themselves, having no husband, the father of the child being unemployed or reluctant or unable to support them, and to inadequacy of government child support grant. These barriers limited their effective care, including their ability to feed the child well:

There are foods which I wish that my child could eat, foods that they told us at the hospital, food that make blood flow, like beetroot, carrots, potatoes, spinach and fruit…I can't get the food because I am not working, I don't have a husband…everything they (health professionals) mentioned needs money…the little money (referring to child support grant) I get for them is not enough it doesn't meet our needs. I can only afford maize meal. (mother, 36 years)

Barriers to healthcare resulting in shortages of drugs, e.g. antibiotics and access to ARVs, because 'we can't collect the treatment because of money' (mother, 30 years). ARVs are provided by only one facility, a public–private partnership distant from many villages in the community. Although the ARVS are free, cost of transport to the agency limits treatment. Additionally, some caregivers feared that health professionals would not maintain confidentiality about their child's HIV status, and others felt that they had bad attitudes and did not respect them. These barriers led caregivers to choose other options, such as attending the more distant hospital:

When we go to the hospital they help us, but at the clinic they have a bad attitude; I went there and I found that they were treating me in a bad manner, I didn't go back there. The way they talk, it doesn't make me feel free. Most times when I want to visit the clinic I go to the mobile clinic…If you take them (children) to the clinic with flu, they say 'these people have one illness; we have a shortage of medicine here at our clinic and they'll use up the drugs for other people'. Most of the time there is no medicine at the clinic and at the end of the month, I buy medicines and headache pills (from a private outlet) and put them away safely (mother, 42 years).

There were also some gaps in information about care, particularly concerning feeding and treatment: 'Myself, I have changed nothing…I still give her the same food because I don't know what kind of food I should give her' (mother, 34 years). At the end of the interviews, several respondents asked about ARVs and indicated an interest in further information. These gaps may indicate differential health seeking or acquisition of information regarding care of HIV positive children, even though all women were referred for counselling and advice.

Various support networks are available to caregivers, including informal social support from relatives and friends, and community-based and government initiatives. Support acquired included emotional support or empathy, instrumental support such as counselling or advice and encouragement to seek care, practical support such as with work, and material support including acquiring food supplements from health facilities and other sources of food and money. A few caregivers borrowed money and food from neighbours, while many depended on the government's child support grant (ZAR240 i.e. approx US$30 per child <15 years per month). Respondents felt that this was inadequate, and one caregiver reported that she could not access the care dependency grant as the child's immune system was still good. Caregivers pleaded for more financial and material support, such as food, from the government. Another salient plea was for the government to find and provide a cure for HIV/AIDS.

Support from other people often followed disclosure of the child's status. Thirteen (62%) respondents had disclosed test results to at least one person, mainly close family members such as child's father, grandparents or siblings, or caregiver's siblings. However, more than half

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of respondents (11, 52%) had not told anyone – 'I don't get any support because it is my secret' (mother, 25 years) – and several caregivers were reluctant to seek support from community-operated home-based care groups due to perceived lack of confidentiality. Only one respondent had joined a support group where members teach each other.

Discussion

One year following the HIV test, most caregivers exhibited positive attitudes to knowing their child's status and maintained high aspirations for the child. Coping happened over time, mainly through counselling and spirituality. Knowledge of HIV status was perceived as valuable since it enhanced caregiver's competency in providing care to the child.

These positive attitudes towards knowing the child's HIV status and the high level of acceptance were unexpected given that stigma is persistent in South Africa (Doherty et al. 2006). Additionally, a child's positive HIV status usually indicates maternal infection. Studies have demonstrated negative anticipated or experienced consequences of perinatal testing of mothers (Gaillard et al. 2002, Medley et al. 2004); these include anxiety, healthcare discrimination, social discrimination, and marital violence and abandonment. Such fears may have implications for the ability of the caregiver (usually the mother) to accept the test results of the child. Acceptance of test results is important as it is closely related to caregiving and adherence to advice from health professionals (Brouwer et al. 2000), while denial of results hinders health-care seeking and social support (Meursing and Sibindi 2000). The high level of acceptance of child's HIV status was associated with counselling and advice given to the caregivers by health professionals and self-spirituality. Positive attitudes may also reflect the healing effects of time in the presence of continuous counselling and other support (Kaleeba et al. 1997, Krabbendam et al. 1998). The negative immediate reactions expressed by several caregivers were expected, as they are similar to those reported among women diagnosed positive during the perinatal period (Gaillard et al. 2002, Medley et al. 2004).

Statements such as 'you opened our eyes' or 'your visit opened my mind' suggest that knowledge of HIV status supports competency in care-giving. The perceived usefulness of knowing a child's HIV status is important as it may promote acceptance and coping with the results and encourage caregivers' aspirations for the child's future, thereby improving the quality of care. The finding on high aspirations in this study differs from views expressed in a Ugandan study, indicating that some mothers would not care for an HIV positive child as the child would die anyway (Brouwer et al. 2000). Although the high aspirations could be real, they may also be unrealistic as studies have documented higher levels of wishful thinking among caregivers of HIV positive children than of HIV negative children (Klunklin and Harrigan 2002).

The barriers to care-giving are important, and mirror those documented with regard to care-giving to HIV positive children elsewhere (Klunklin and Harrigan 2002) and among people living with HIV in other South African settings (Hardy and Richter 2006). Financial restrictions were a major limitation. Although most respondents regarded it as inadequate, most depended on the government's child support grant, and since many of the mothers were also infected, their opportunities for formal employment were limited. The financial and physical limitations indicate need for creative and effective income generating strategies as evidenced in other settings (Kompaore 2004). Further, the disability grant offered by the South African government to the people aged 18–65 years with physical and mental disability provided good support to people living with HIV/AIDS (Venkataramani et al. 2009). However, they only qualify if they are too sick to work and may lose it if their health improves as may occur with ARV treatment (Nattrass 2006, Hardy and Richter 2006). This policy may need revision to allow access before disability sets in, particularly so for mothers who are HIV positive and are also taking care of HIV positive children. The care dependency grant targeted at children with disability less than 18 years could be useful in caring for HIV positive children. However, it may also need revision as these children only access it when they reach the later disabling stages of the disease (Makino 2003).

Many caregivers obtained support from others in care-giving, particularly from relatives. However, few mentioned accessing special support and services geared specifically towards people living with AIDS, such as food supplements or being in support groups. This may relate to stigma associated with HIV, hindering caregivers from disclosing the child's status outside the family and inhibiting access to special external support. This reluctance may also relate to attitudes anticipated or experienced by respondents from health professionals. Interventions, including education and motivation, to improve the practice of health-care professionals are therefore needed. Further, despite the perceived utility of knowing a child's HIV status, there was also apparent reluctance to transfer this knowledge to the next-line caregiver. This was evident where the child's mother had died, as most nonmaternal caregivers were unaware of the child's status. This indicates need for re-emphasis of disclosure at least to potential next-line caregivers.

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Support groups may play a major role in providing continuous counselling and mentorship to caregivers of infected children, important in building resilience (Krabbendam et al. 1998). However, few reported joining a support group, suggesting a gap in awareness of the value or stigma associated with seeking HIV-related support and services. Additionally, there was little mention of support from nongovernmental organisations such as home-based care groups located in the community. This may be because support often followed disclosure, and caregivers mentioned fear of lack of confidentiality as inhibiting disclosure to home-based carers. These organisations could play a major role in reducing barriers to care, as they would bring services closer to people. There is need for awareness of their role in the community and education of home-based carers on confidentiality to enhance client confidence.

Prevention of mother to child transmission programmes are critical in preventing paediatric HIV infection and should be promoted. Where PMTCT programmes fail, interventions to improve health and wellbeing of infected children are paramount. Given the low survival of HIV positive children in the absence of interventions (Brahmbhatt et al. 2006), the findings of this study indicate the importance of community-based paediatric HIV screening in settings with high HIV prevalence to ensure early and appropriate interventions for children living with HIV to improve the growth of infected children (Kabue et al. 2008). However, as illustrated, there is limited access due to financial barriers relating to cost of transport, and lack of adequate information on ARVs; a limited number of facilities close to the communities where people can be initiated onto ART, and a need for step-down facilities for monitoring and treatment. The shortage of drugs for opportunistic infections mentioned also needs government intervention.

Study limitations relate to the design and small sample of participants; hence we cannot quantify the impact of knowing a child's HIV status on child care, nor factors associated with coping. Results on immediate and subsequent reactions to learning a child's positive HIV status may have been affected by recall bias as there was no regular observation of the study participants during the follow-up period. However, this study raises important questions that could be followed-up with a larger sample, using both qualitative and quantitative measures, with regular follow-up visits to participants.

In settings with high HIV prevalence, early paediatric HIV testing could facilitate early introduction of appropriate interventions such as ART, and nutritional support to promote survival of infected children. Further research is indicated into the usefulness of community-based paediatric HIV testing quantitatively using large samples and in different contexts. The information from this study, and future studies, is important for policy and public health interventions to improve the health, survival and general wellbeing of HIV positive children in South Africa and similar settings.

Acknowledgements

We acknowledge funding from the National Research Foundation (NRF), the Medical Research Council (MRC) and the Faculty of Health Sciences, University of the Witwatersrand, South Africa, where Lenore Manderson was Hillel Friedland Fellow in 2008. The AHDSS is funded by the Wellcome Trust, UK (Grant no. 069683/Z/02/Z). Elizabeth Kimani-Murage has a PhD fellowship funded by the Flora and William Hewlett Foundation, USA, while Dr Shane Norris is on a Wellcome Trust funded fellowship. We acknowledge logistical support from the MRC/Wits Rural Public Health and Health Transitions Research Unit (Agincourt) during data collection and the African Population and Health Research Center (APHRC), Kenya during preparation of this manuscript. We acknowledge the data collection team and Rhian Twine, Jeffrey Tibane and Audrey Khosa for their role in community mobilisation. We acknowledge the data entry team from the MRC Mineral Metabolism Research Unit, University of the Witwatersrand and Amukelani Nkuna, a student at the University of the Witwatersrand for her assistance in data cleaning. We acknowledge technical support from Prof John Pettifor, Prof Stephen Tollman and Ms Nicola Christofides of the University of the Witwatersrand, Dr Martin Murage of Kenyatta National Hospital, Kenya and Dr Chichi-Undie of the APHRC. This work was presented and reviewed at a seminar at the School of Public Health, University of the Witwatersrand.

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Paper IV

Kimani-Murage EW. Kahn K, Pettifor JM, Tollman SM, Klipstein Grobusch K, Norris SA. Predictors of adolescent obesity and risk for metabolic Disease in rural South Africa (Submitted, Journal of Adolescent Health)

Predictors of adolescent obesity and risk for metabolic disease in rural South Africa

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Abstract

Background: Childhood and adolescent obesity is an increasingly important public health concern and the driving force for the increasingly important paediatric metabolic syndrome in low-to-middle income countries (LMICs). Predictors of Childhood and adolescent obesity are not yet clear particularly in LMICs. This study aims at determining the child, maternal, household and community level determinants of adolescent weight status and risk for metabolic disease.

Methods: The study is based on data from 1848 adolescents aged 10-20 years, collected in 2007 in Agincourt, rural South Africa. Height, weight and waist circumference were taken using standard procedures. Overweight and obesity in adolescents 10-17 years were determined using International Obesity Taskforce cut-offs. For adolescents 18 to 20 years, adult cut-off points of BMI =25 and =30 kg/m^2 for overweight and obesity respectively were used. Waist circumference cut-offs of =94cm for males and = 80cm for females were used to determine central obesity indicating risk for metabolic disease. Linear and logistic regression analysis were done to determine risk factors .

Results: Prevalence of combined overweight and obesity was significantly higher in girls (15%) than in boys (4%) and likewise for central obesity: 12% and 1% for girls and boys respectively. Key predictors of weight status and central obesity included at child level: child's age, sex and pubertal development and at household level: household head's highest education level, food security and SES.

Conclusions: This findings indicate need for interventions at child and houseld level to curb adolescent obesity that is increasingly important in LMICs. Given the gender biased risk observed, gender sensitive strategies particularly are recommended. Further, interventions should particularly consider affluency and related behaviours such as sedentary lifestyles as those in higher SES households were at increased risk.

Key Words: Adolescent, overweight, obesity, central obesity, developing countries, low-to-middle income countries, South Africa, rural.

Introduction

Obesity is increasingly a public health concern in both the high income and the low-to-middle income countries (LMICs), but the prevalence of obesity is expected to increase more rapidly in LMICs (1, 2). The high level of obesity in these countries is associated with a rise in chronic diseases such as hypertension, coronary heart disease, Type II diabetes and certain types of cancers which contribute substantially to the burden of disease (2). Childhood and adolescent obesity is of a particular concern, as obese children and adolescents are more likely to become obese adults and are at higher risk of metabolic diseases (3, 4). In South Africa, high levels of overweight/obesity have been documented among adults (5). There is also some evidence of high levels of overweight/obesity among children and adolescents (6, 7). In a recent study in Agincourt, rural South Africa, we described patterns of overweight/obesity and central obesity among children and adolescents aged 1-20 years. The prevalence of combined overweight and obesity was high in adolescent girls, reaching a peak of 25% at age 18 years, while central obesity was also high in adolescents, increasng with pubertal development, reaching a peak of 35% in girls in Tanner stage 5 (Kimani-Murage et al., unpublished).

Predictors of child and adolescent obesity have been described in various studies (8, 9). In a review of literature, Davison (2001) described an ecological model of predictors of child weight status. Under the model, child characteristics interact with familial/household and societal/community factors to influence weight status in a child. Child's behavioral patterns including dietary intake, sedentary behaviours and physical activity predict child's weight status (9). On the other hand, child characteristics including sex, age and genetic susceptibility to gaining weight (9, 10) moderate the impact of child behavioral patterns on the development of obesity. Additionally, family/household factors such as socio-economic (SES) factors, parenting styles, parental dietary patterns, and sibling interactions (8, 10, 11)influence child's weight status through shaping the development of child behavioral patterns. Community and the wider societal and environmental

factors influence the weight of the child through influencing the child behavioural patterns and family factors (9).

There are limited studies describing the predictors of child and adolescent obesity in rural South Africa (12). This study aims at exploring associations between child, maternal, household and community level factors and obesity and risk for metabolic diseases among adolescents aged 10-20 years, randomly selected from a contemporary rural South African setting.

Data and Methods

Study Setting and Population

This study was conducted in the Agincourt sub-district of Mpumalanga Province, in rural northeast South Africa alongside the country's border with Mozambique. It was nested within the Agincourt health and socio-demographic surveillance system (HDSS). The Agincourt HDSS was established in 1992 and covers the entire Agincourt sub-district. It follows some 70,000 people living in 11,700 households in 21 contiguous villages. The population comprises Tsonga-speaking people, some 30% of whom are of Mozambican origin, having entered South Africa mainly as refugees in the early to mid-1980s following the civil war in Mozambique. Despite government development initiatives, infrastructure remains limited in Agincourt. The area is dry with household plots too small to support subsistence farming. Poverty level is high (13), and labour migration is widespread involving up to 60% of working age men and increasing numbers of women (14, 15). The study area and local demographics are described in detail elsewhere (16).

Data

We conducted a growth survey between April and July 2007 which was nested within the

Agincourt HDSS described above. The survey targetted 4000 children and adolescents aged 1 to 20 years, comprising 100 males and 100 females for each year of age, comprising about 12% of the total population in the Agincourt HDSS within this age-spectrum. Participants had lived in the study area at least 80% of the time since birth, or since 1992 when enrolment in the Agincourt HDSS began. A total of 3511 (close to 80% of the sample) participated in the study. For the purpose of this study, data included are for 1848 adolescents aged 10-20 years.

Anthropometric measurements were carried out on all the participants. This was done by a team of 12 fieldworkers who were carefully trained by experts in anthropometric measurements. Height was measured using a stadiometer (Holtain, UK) calibrated in millimeters. Weight in kilograms (to one decimal point) was determined using a mechanical bathroom scale (Hanson, UK). Waist circumference was measured in millimeters using an inelastic tape measure (Holtain, UK), at the natural waist, i.e. midway between the tenth rib and the illiac crest with the participant in a standing position. All measurements were taken according to standard procedures (17). Pubertal assessment in children 9 years and older was obtained using the Tanner 5-point pubertal self-rating scale that reflects physical development based on external primary and secondary sex characteristics: pubic hair in girls and boys, breast development in girls and genitalia in boys (18). Genital development in boys and breast development in girls were used to define the stages in this study.

Explanatory variables used in this study (described below) including child, maternal, household and community level factors were obtained from the Agincourt HDSS. The Agincourt HDSS is a multiround prospective community study and involves systematic annual recording of all births, deaths and migration events occuring in Agincourt since 1992. Individual characteristics including date of birth, sex, and nationality of origin are recorded. Additional data are collected as special census modules nested within the annual update rounds. These include education,

child social grant uptake, union status and food security. An asset survey conducted in each household every two years gives a measure of household socioeconomic status. Data collected in 2007 for the various variables was used.

Measures

Outcome measures

Outcome measures include body mass index (BMI), waist cicumference, combined overweight and obesity, and central obesity. BMI was determined by dividing weight (in kg) by height squared (in metres). Overweight and obesity in children 10-17 years were determined using the absolute age and sex specific cut-offs for BMI recommended by the International Obesity Taskforce (IOTF) (19). These are defined to pass through BMI of 25 and 30 kg/m2 at 18 years for overweight and obesity respectively. For adolescents 18 to 20 years, adult cut-off points of BMI =25 and =30 kg/m2 for overweight and obesity respectively were used. Therefore overweight/obesity in this study refers to either overweight or obesity determined using the above BMI criteria. Waist circumference was used as a continuous variable. Additionally, waist circumference cut-offs of =94cm for males and = 80cm for females were used to determine those at risk of metabolic disease (referred to as central obesity in this paper) as defined by the World Health Organization and used by the International Diabetic Federation (IDF) to define the metabolic syndrome with reference to sub-Saharan Africans (20).

Explanatory variables

Explanatory variables were derived from the Agincourt HDSS data set described above. Child level factors included: child age, sex and pubertal development status; maternal factors included: mother's age, nationality, highest education level, marital/union status and co-residence with child; household level factors included: household head age, sex, highest education level, and relationship

to child, household food security and household SES; area of residence was used as a proxy for community level characteristics.

Definition of most of the explanatory variables is self explanatory as stipulated in Table 1 below. For pubertal status, a binary variable was constructed with those in Tanner stage 1 defined as pre-pubertal and those in Tanner stages 2-5 defined as pubertal. Food insecurity was defined as not having reported enough food to eat either in the last one month or in the last one year, whereas food secure households were characterized as households reporting sufficient to eat both in the last one month and one year respectively. Data on usual frequency of consumption of certain common food items including chicken, fish, red meat, eggs, maize, rice, potatoes, bread, green vegetables and wild foods (wild vegetables/herbs and fruits) was also included. Frequency of consumption was rated as rare if on average a food item was consumed less than once per week; sometimes if it was consumed at least once but less than 3 times per week; often if it was consumed at least 3 times but less than 6 times per week; and daily if it was consumed 6 or more times per week. Household wealth index was constructed from household assets (21) including type and size of dwelling; water and sanitation facilities; electricity; modern assets such as fridge and television; transport assets such as bicycle and car; communication assets such as cellphone; and livestock such as cattle. A composite score for the wealth indicator was constructed. Household wealth tertiles were generated from the composite SES score using the Stata's xtile command and labelled as most poor (lowest 1/3), middle class, and least poor (highest 1/3).

Ethical Clearance

For the growth study, written informed consent was obtained from the parent/caregiver of children/adolescents aged less than 18 years and from adolescents 18-20 years themselves, while assent was also obtained from those aged 9-17 years. Verbal consent is routinely obtained from participants of the Agincourt HDSS. Ethical clearances for the growth survey and the Agincourt

HDSS were granted seperately by the University of the Witwatersrand Committee for Research on Human Subjects, (Medical). Ethical clearance number for the 2007 growth survey is M070244, while for the Agincourt HDSS is M960720.

Statistical Analysis

Data analysis was done using Stata version 10.0 (StataCorp LP, College Station, Texas, USA). Student T-test was used to determine difference in means while Chi-square test was used to determine difference in proportions. Univariate and multiple linear and logistic regression were done with outcome variables (BMI, Waist circumference, overweight/obesity, central obesity) and explanatory variables as described above, respectively. Missing values for each variable were allocated an independent category in the regression models to maintain all participants in the analysis. The variables affected include: mother's age (9%), mother's nationality (9%), mother's education (21%), household head education (11%), household head relationship with child (<1%), food security (4%) and social economic status (2%). Only explanatory variables found to be significantly associated with the outcome variable at the 10% level of significance in the univariate analysis were included in the multiple regression analysis. A p-value of <0.050 was considered statistically significant.

Results

The study comprised of 903 (49.6%) boys and 945 (50.5%) girls, aged 10-20 years; mean age 14.6 (95% CI; 14.43, 14.83). There was no significant difference in mean age by sex.

Prevalence of combined overweight and obesity and central obesity

The prevalence of combined overweight and obesity, measured using BMI cut-offs was 10%; higher in girls (15%) than boys (4%) (p<0.001). It was highest in girls aged 15-20 years (19%). It was significantly higher in girls than in boys in both age categories 10-14 and 15-20 years

(p<0.001, respectively). The prevalence of central obesity, measured using waist circumference cut-offs was 6%; higher in girls (12%) than boys (1%) (p<0.001). It was low in the age category 10-14 years and very high in the age category 15-20 years, particularly for girls (19%). Like for overweight/obesity, it was higher in girls than in boys in both age categories 10-14 and 15-20 years (p<0.001, respectively). (Figure 1).

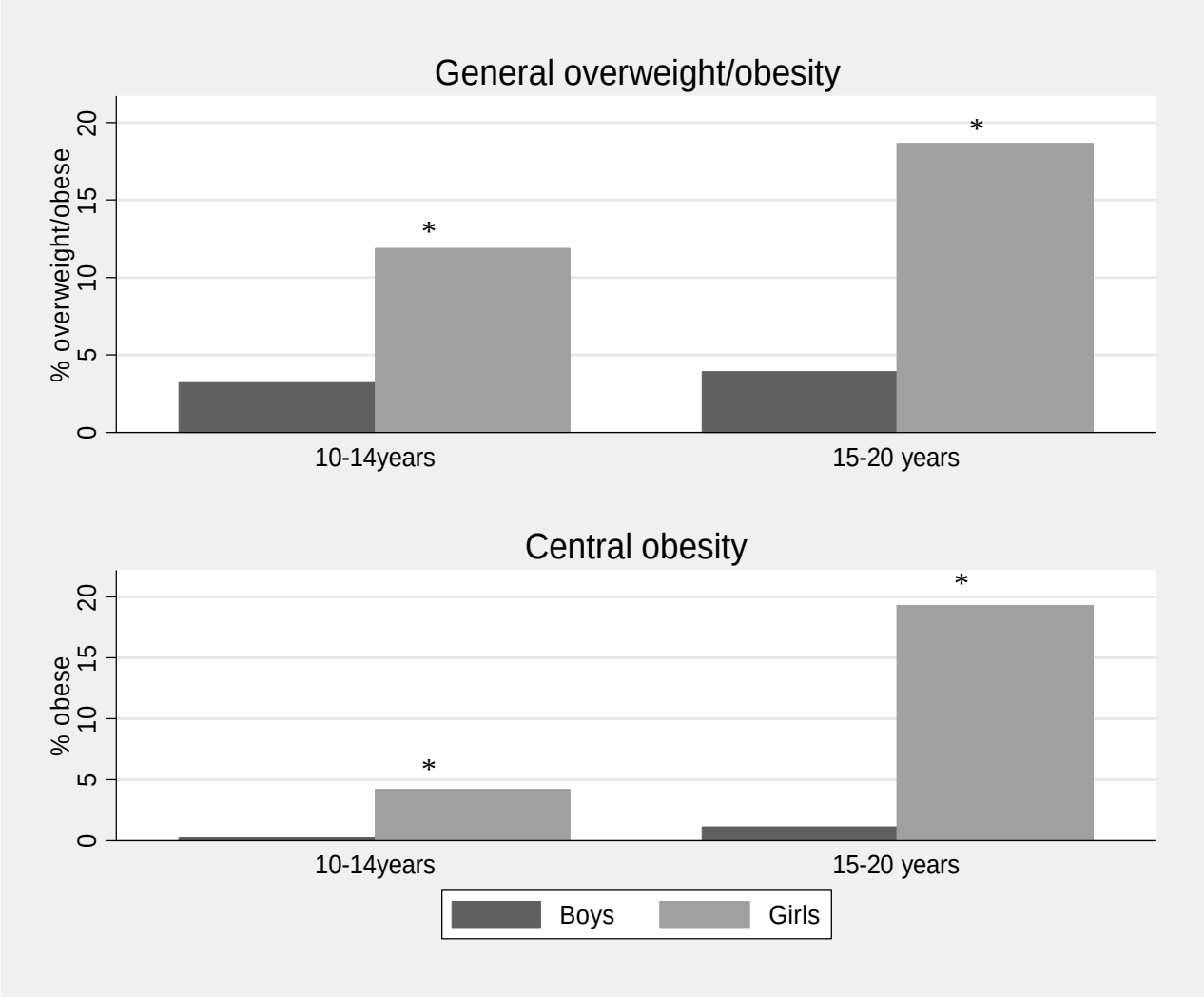

Figure 1: Combined overweight/obesity and central obesity for adolescents aged 10-20 years by sex, Agincourt sub-district, South Africa, 2007. (Significant difference by sex: *P-value <0.05) (N=1848)

Distribution of overweight/obesity and central obesity by explanatory variables

Table 1 shows distribution of combined overweight and obesity and central obesity with respect to various covariates. With regards to combined overweight and obesity, the following categories had significantly higher prevalence: adolescents aged 15-20 years (p=0.003), girls (P<0.001), those who had attained puberty (p=0.001), adolescents of mothers aged 50+ years (p=0.015), adolescents whose mothers were of South African origin (p=0.023), adolescents whose household heads had completed secondary or higher education (p=0.022), adolescents from least poor households (p=0.002) and adolescents from villages predominantly inhabited by people of South African origin (p=0.047). With regards to central obesity, adolescents aged 15-20 years (P<0.001), girls (P<0.001), those who had attained puberty (p<0.001), adolescents of mothers aged 50+ years (p=0.005), adolescents whose household heads had no education or had completed secondary or higher education (p=0.034) and adolescents in food secure households (p=0.004) had significantly higher prevalence.

Table 1: Distribution of combined overweight and obesity and central obesity by various covariates for adolescents aged 10-20 years, living in Agincourt, South Africa, 2007 (N=1848)

Variable	N (%)	Combined overweight & obese (%)	Central obesity (%)
Child's Characteristics			
Child Age		P=0.003	P<0.001
10-14	944 (51.1)	7.5	2.22
15-20	904 (48.9)	11.6	10.63
Sex		P<0.001	P<0.001
Boys	903 (49.6)	3.5	0.7
Girls	945 (50.5)	15.2	11.75
Pubertal Status		P=0.001	P<0.001
Pre-pubertal	283(15.3)	4.2	0
Pubertal	1565 (84.7)	10.5	7.5
Mother's Characteristics			
Mother's Age (current)		P=0.015	P=0.005
15-34	302 (8.0)	8.3	3.3
35-49	1001 (59.7)	8.2	6.1
50+	373 (22.3)	13.1	9.4
Mother's Nationality		P=0.023	P=0.341
South African	1131 (67.5)	10.4	6.73
Mozambican	544 (32.5)	7.0	5.51
Mother's Education		P=0.949	P=0.642
No formal education	547 (37.4)	9.0	5.85
Some Primary, Completed Primary, Some Secondary	659 (45.1)	8.5	5.93
Completed Secondary/Matric, Higher	255 (17.5)	9.0	7.45
Marital/Union Status		P=0.862	P=0.320
Currently in union	944 (51.1)	9.6	6.9
Not in union	904 (48.9)	9.4	5.8
Co-Residence with Child		P=0.575	P=0.413
Alive, co-residing	1536 (83.1)	9.5	6.6
Alive, not co-residing	163 (8.8)	10.7	5.5
Dead	149 (8.1)	8.7	4.0
Household Characteristics			
Household Head's Age		P=0.296	P=0.638
15-49	739 (40.0)	8.7	6.0
50+ years	1107 (60.0)	10.1	6.5
Household Head's Sex		P=0.131	P=0.324
Male	1207 (65.4)	8.8	5.9
Female	639 (34.6)	11.0	7.1
Household Head's Education		0.022	P=0.034
No formal education	806 (49.1)	10.3	7.2
Some Primary, Completed Primary, Some Secondary	692 (42.2)	7.4	4.2
Completed Secondary/Matric, Higher	143 (8.7)	14.0	7.7
Household Head's Relation to Child		P=132	P=0.255
Parent	1272 (68.8)	8.8	6.4
Grandparent	430 (23.3)	12.9	8.5
Other relative	140 (7.6)	10.0	3.5
Enough Food (last month/year)		P=0.073	P=0.004
Yes	1443 (8.2)	10.4	7.4

Not enough	335 (18.8)	7.2	3.0
Wealth Index Tertiles		P=0.002	P=0.369
Most Poor	605 (33.4)	6.8	5.5
Middle	603 (33.3)	9.6	6.5
Least Poor	603 (33.3)	12.8	7.5
Community Factors			
Area of Residence		P=0.047	P=0.541
Predominantly S. African	1746 (94.5)	9.9	6.4
Predominantly Mozambican	102 (5.5)	3.9	4.9

Food security and consumption of various food items

About one in five of the households were reportedly food insecure (did not have enough to eat in the last one month or one year). Food (in)security status was significantly associated with SES ($p<0.001$): 27%, 16% and 13% of food insecure households were in the most poor, middle and least poor category respectively.

Table 2 shows frequency of consumption of various food items (chicken, fish, red meat, eggs, maize, rice, potatoes, bread, green vegetables and wild foods) by food security status and SES. Clearly, food secure households significantly consumed all the food items more frequently than the food insecure households ($P<0.05$, respectively) but for vegetables, wild foods and maize. Food insecure households consumed vegetables ($p=0.005$) and wild foods ($p=0.002$) more often, while there was no difference in the consumption of maize ($p=0.451$). Similarly, least poor households significantly consumed the various food items more frequently ($p<0.001$, respectively) but for fish, maize, vegetables and wild foods. Most poor households consumed fish ($p=0.001$), and vegetables ($P<0.001$) more often than households in the other SES classes. Though maize was consumed by almost all households on a daily basis, most poor households seemed to consume it more often ($p<0.001$).

Table 2: Consumption of various food items by food security status, SES, and obesity status for adolescents aged 10-20 years, living in Agincourt, South Africa, 2007 (N=1848)

Food Item	Food Security Status (%)		SES (%)		
	Secure (%)	Insecure (%)	Most Poor (%)	Middle (%)	Least Poor (%)
Chicken	P<0.001		P<0.001		
Rarely[1]	5.8	24.5	17.6	6.9	4.3
Sometimes[2]	44.3	49.9	52.7	44.7	38.4
Often[3]	46.9	23.3	28.0	46.6	52.6
Daily[4]	2.9	2.4	1.7	1.9	4.8
Fish	P=0.003		P=0.001		
Rarely	19.4	26.4	21.3	16.5	24.5
Sometimes	52.5	48.1	48.2	53.5	53.4
Often	27.3	23.3	29.3	29.3	20.7
Daily	0.8	2.2	1.3	0.7	1.3
Red meat	P<0.001		P<0.001		
Rarely	62.8	81.6	78.2	70.0	52.3
Sometimes	30.7	15.2	18.4	23.7	39.8
Often	5.9	3.3	3.4	5.6	7.1
Daily	0.6	0.0	0.0	0.6	0.8
Eggs	P<0.001		P<0.001		
Rarely	25.8	46.2	45.6	28.4	17.1
Sometimes	24.7	26.9	24.2	28.2	23.3
Often	31.9	19.4	24.8	29.4	33.4
Daily	17.7	7.5	5.4	13.9	26.2
Maize	P=0.4510		P<0.001		
Rarely	0.4	0.0	0.9	0.2	0.0
Sometimes	0.6	0.6	0.4	0.5	1.0
Often	5.0	3.6	2.4	4.1	7.7
Daily	93.9	95.8	96.4	95.2	91.3
Rice	P<0.001		P<0.001		
Rarely	20.4	48.1	41.2	22.0	14.0
Sometimes	75.3	47.8	55.4	74.2	80.5
Often	3.5	1.9	2.9	2.8	3.9
Daily	0.8	2.2	0.5	1.1	1.5
Potatoes	P<0.001		P<0.001		
Rarely	48.9	62.2	61.0	52.6	42.0
Sometimes	39.8	26.5	30.7	37.9	42.7
Often	9.4	10.0	6.7	8.7	12.3
Daily	2.0	1.4	1.6	0.8	3.0
Bread	P<0.001		P<0.001		
Rarely	1.9	10.6	7.3	1.9	1.9
Sometimes	6.1	14.9	12.0	8.8	2.7
Often	17.4	31.8	31.5	17.0	11.9
Daily	74.5	42.7	49.2	72.3	83.5
Vegetables	P=0.005		P<0.001		
Rarely	7.4	5.8	4.9	8.8	7.7
Sometimes	39.6	36.2	34.3	36.9	45.6
Often	40.7	38.3	47.2	38.5	35.4
Daily	12.2	19.6	13.6	15.9	11.4
Wild foods	P=0.002		P=0.063		
Rarely	32.5	26.4	29.3	29.4	35.1
Sometimes	45.1	41.8	42.3	48.3	42.7
Often	20.3	27.4	25.6	19.7	20.0
Daily	2.1	4.4	2.8	2.6	2.2

[1]Rare=less than once a week; [2]Sometime=More than once but less than thrice a week; [3]Often=Three times or more but less than six times a week [4]Daily=Six times or more a week

Multivariate Analysis

Predictors of BMI, waist circumference, overweight/obesity and central obesity are presented in Tables 3 and 4 below. Only variables that were significantly associated with the outcome measures at the 10% level of significance from univariate analysis are included in the tables. Test for collinearity among the variables included in the multivariate analysis was done. There was no significant collinearity. Additionally, interaction was tested between various variables significant at univariate level; no significant interactions were found. Key predictors of child's weight status and central obesity were at child and household level. Maternal level factors including age, nationality and area of residence at community level were significantly associated at univariate level but not at multivariate analysis level.

Child factors

All the child level factors examined (age, sex and pubertal development status) emerged as key predictors of child's weight status and central obesity. After controlling for other covariates, for every increase in one year, BMI increased by 0.5 kg/m^2 ($p<0.001$); waist circumference increased by 1.4cm ($p<0.001$), odds of combined overweight and obesity increased 1.1 times ($p=0.030$), while odds of central obesity increased 1.3 times ($p<0.001$). Compared to boys, girls had close to 2 kg/m^2 higher BMI, had 1.6cm wider waist circumference, had 5-fold odds of being overweight or obese ($p<0.001$) and had a 21-fold odds of having central obesity ($p<0.001$, respectively). Compared to pre-pubertal adolescents, pubertal adolescents had 1 kg/m^2 higher BMI ($P<0.001$), had 3.0cm wider circumference ($P<0.001$) (Tables 3 & 4)

Household factors

After controlling for other covariates, key household level predictors included household head education level, food security and SES. Compared to adolescents in households headed by someone with no formal education; adolescents from households headed by someone who had completed

primary or had some secondary level education but no secondary level certificate were less at risk of overweight/obesity and central obesity, with 0.6 times odds of having overweight/obesity (p=0.018) and 0.6 times odds of having central obesity (p=0.027). With regards to household food (in)security, compared to those in food secure households, adolescents in food insecure households had lower BMI; 0.4 kg/m^2 lower (p=0.040), had narrower waist circumference; 1.0cm narrower (p=0.020) and had lower odds of having central obesity; 0.3 times (p=0.002). Compared to adolescents in most poor households, those from the middle class had 0.5 kg/m^2 higher BMI (p=0.017), while those from least poor households had 0.8 kg/m^2 higher BMI (p<0.001). Similarly, those from least poor households had 1.0cm wider waist circumference (p=0.013). Additionally, those from the least poor households had close to two-fold odds of having overweight/obesity compared to those in most poor households (p=0.004). (Tables 3 & 4)

Table 3: Determinants of body mass index and combined overweight and obesity in adolescents 10-20 Years, Agincourt sub-district, rural South Africa, 2007 (N=1848)

Variable	BMI (kg/m2)*		Overweight & Obesity**	
	Univariate Coeff (95% CI) P	Multivariate Coeff (95% CI) P	Univariate OR (95% CI) P	Multivariate OR (95% CI) P
Intercept		9.3 [8.5, 10.2] <0.001		
Child Characteristics				
Child age (n=1848)	0.6 [0.6, 0.7]<0.001	0.5 [0.5, 0.6]<0.001	1.1 [1.0, 1.1] 0.001	1.1 [1.0, 1.1] 0.030
Child Sex				
Boys (n=903) (ref)	0	0	1	1
Girls (n=945)	2.0 [1.6, 2.3]<0.001	1.8 [1.5, 2.1]<0.001	4. 9 [3.3, 7.3]<0.001	4.9 [3.3, 7.3]<0.001
Pubertal Status				
Pre-pubertal (n=283)	0	0	1	1
Pubertal (n=1565)	3.7 [3.2, 4.1]<0.001	1.0 [0.5, 1.4]<0.001	2.6 [1.5, 4.8] 0.002	1.3 [0.7, 2.5] 0.461
Maternal Characteristics				
Mother's age category				
35-49 (n=1001) (ref)	0	0	1	1
15-34 (n=302)	-0.5 [-2.0, -1.0]<0.001	0.2 [-0.3, 0.6] 0.521	1.0 [0.6, 1.6] 0.962	1.4 [0.8, 2.3] 0.235
50+ (n=373)	1.1 [0.6, 1.5]<0.001	0.2 [-0.3, 0.6] 0.493	1.7 [1.2, 2.5] 0.006	1.5 [1.0, 2.2] 0.063
Mother's Nationality				
South African (n=1131) (ref)	0	0	1	1
Mozambican (n=544)	-0.9 [-1.3, -0.5]<0.001	-0.3 [-0.6, 0.1] 0.173	0.6 [0.4, 0.9]0.024	0.8 [0.5, 1.3] 0.365
Household Characteristics				
HHH Age				
15-49 (n=739) (ref)	0	0		
50 + (n=1107)	0.5 [0.1, 0.9] 0.008	-0.0 [-0.4, 0.4] 0.830		
HHH Sex				
Male (n=1207) (ref)	0	0		
Female (n=639)	0.3 [-0.0, 0.7] 0.078	-0.2 [-0.1, 0.6] 0.155		
HHH Education				
No education (n=806) (ref)				
Some primary, completed primary, some secondary (n=692)			0.7 [0.5, 1.0] 0.049	0.6 [0.4, 0.9] 0.018
Completed secondary/Tertiary (n=143)			1.4 [0.8, 2.4] 0.193	1.2 [0.7, 2.2] 0.479
Relationship to child				
Parent (n=1272) (ref)	0	0		
Grandparent (n=430)	-0.7 [-1.1, -0.2] 0.002	-0.2 [-0.8, 0.3] 0.383		
Other relative (n=140)	-0.5 [-1.2, 0.20] 0.165	-0.3 [-0.9, 0.3] 0.297		
Food Security				
Enough (ref)	0	0	1	1
Not enough	-0.6 [-1.0, -0.1] 0.015	-0.4 [-0.8, -0.0] 0.040	0.7 [0.4, 1.0] 0.075	0.7 [0.4, 1.1] 0.141
SES Tertiles				
Most poor (n=605) (ref)	0	0	1	1
Middle (n=603)	0.6 [0.2, 1.1] 0.005	0.5 [0.1, 0.8] 0.017	1.5 [1.0, 2.2] 0.073	1.4 [0.9, 2.1] 0.148
Least poor (n=603)	1.0 [0.6, 1.5]<0.001	0.8 [0.4, 1.2]<0.001	2.0 [1.4, 3.0] 0.001	1.9 [1.2, 2.9] 0.004
Area of Residence				
Predominantly S. African (n=1746) (ref)	0	0	1	1
Predominantly Mozambican (n=102)	-1.0 [-1.7, -0.2] 0.014	-0.2 [-0.9, 0.5] 0.566	0.4 [0.1, 1.0] 0.057	0.5 [0.2, 1.5]0.220
R-squared		0.32		

* Linear regression

** Logistic Regression

Table 4: Determinants of waist circumference and central obesity in adolescents 10-20 Years, Agincourt sub-district, rural South Africa, 2007 (N=1848)

Variable	Waist Circumference (cm)*		Central Obesity**	
	Univariate Coeff (95% CI) P	Multivariate Coeff (95% CI) P	Univariate OR (95% CI) P	Multivariate OR (95% CI) P
Intercept		44.0[42.2,45.8]<0.001		
Child Characteristics				
Child age (n=1848)	1.6 [1.5, 1.7]<0.001	1.4 [1.2, 1.5] <0.001	1.3 [1.2, 1.4]<0.0001	1.3 [1.2, 1.4]<0.001
Child Sex				
Boys (n=903) (ref)	0	0	1	1
Girls (n=945)	2.2 [1.4, 2.9]<0.001	1.6 [1.0, 2.3]<0.001	19.9 [8.7, 45.4]<0.001	21.0 [9.1, 48.4]<0.001
Pubertal Status				
Pre-pubertal (n=283) (ref)	0	0	1	1
Pubertal (n=1565)	9.1 [8.1, 10.1]<0.001	3.0 [2.1, 4.0]<0.001	Dropped***	Dropped***
Maternal Characteristics				
Mother's age category				
35-49 (n=1001) (ref)	0	0	1	1
15-34 (n=302)	-4.0 [-5.1, -2.9]<0.001	0.1 [-0.9, 1.1] 0.821	0.5 [0.3, 1.0] 0.066	1.2 [0.5, 2.5] 0.697
50+ (n=373)	2.6 [1.6, 3.6]<0.001	0.6 [-0.4, 1.6] 0.249	1.6 [1.0, 2.5] 0.035	1.0 [0.6, 1.7] 0.871
Mother's Nationality				
South African (n=1131) (ref)	0	0		
Mozambican (n=544)	-1.9 [-2.7, -1.0]<0.001	-0.5 [-1.3, 0.2] 0.188		
Household Characteristics				
HHH Age				
15-49 (n=739) (ref)	0	0		
50 + (n=1107)	1.0 [0.2, 1.8] 0.010	-0.3 [-1.2, 0.5] 0.451		
HHH Sex				
Male (n=1207) (ref)	0	0	1	1
Female (n=639)	0.1 [0.0, 0.2] 0.068	-0.6 [0.1 1.3] 0.102	1.0 [1.0, 1.1] 0.049	1.1 [0.7, 1.7] 0.656
HHH Education				
No education (n=806) (ref)	0	0	1	1
Some primary, completed primary, some secondary (n=692)			0.6 [0.4, 0.9] 0.015	0.6 [0.3, 0.9] 0.027
Completed secondary/Tertiary (n=143)			1.1 [0.6, 2.1] 0.833	1.3 [0.6, 2.7] 0.479
Relationship to child				
Parent (n=1272) (ref)	0	0		
Grandparent (n=430)	-1.7 [-2.6, -0.8]<0.001	-0.2 [-1.3, 0.9] 0.669		
Other relative (n=140)	0.8 [-2.3, 0.7] 0.283	-0.3 [-1.5, 1.0] 0.677		
Food Security				
Enough (ref)	0	0	1	1
Not enough	-1.2 [-2.2, -0.2] 0.016	-1.0 [-1.8, -0.2] 0.020	0.4 [0.2, 0.8] 0.005	0.3 [0.2, 0.7] 0.002
SES Tertiles				
Most poor (n=605) (ref)	0	0		
Middle (n=603)	1.2 [0.2, 2.1] 0.014	0.7 [0.08, 1.5] 0.078		
Least poor (n=603)	1.6 [0.6, 2.5] 0.001	1.0 [0.2, 1.8] 0.013		
Area of Residence				
Predominantly S. African (n=1746) (ref)	0	0		
Predominantly Mozambican (n=102)	2.0 [-3.7, -0.3] 0.019	-0.4 [-1.9, 1.0] 0.545		
R squared		0.38		

* Linear regression

** Logistic Regression

*** Dropped as no pre-pubertal adolescents were centrally obese

Summary of predictors

Key predictors of weight status and central obesity among adolescents in this community include child level factors: child's age, sex and pubertal development status and household level factors: household head's highest education level, food security and SES. Maternal level factors and area of residence were not significant predictors.

Discussion

This study has described key predictors of weight status and risk for metabolic disease among adolescents aged 10-20 years living in contemporary rural South Africa. The study has demonstrated that significant predictors are at child level including age, sex, and pubertal development and at household level including highest education level of the household head, food security status and SES. Other household level characteristics including household head age, sex and relationship to child; maternal factors including mother's age, nationality, highest education level, marital/union status and co-residence with child and area of residence as a proxy for community level factors were also examined but did not emerge as significant predictors. Identifying context-specific predictors of the increasingly important problem of childhood and adolescent obesity is an important step in its prompt containment given its link to the rising problem of paediatric metabolic syndrome in LMICs (22).

Consistent with other studies (9), child level factors emerged as key predictors of child's weight status and central obesity. Weight and central obesity increased with increase in age and were associated with pubertal development. This may reflect effect of factors such as increased sedentary behaviour and decreased physical activity with age and pubertal onset (23) which may be explained by consequent physical, social and emotional changes (24). The increased risk of obesity among girls in this study is in keeping with many studies in other LMICs (25) and in South Africa in particular (6). Several factors may explain the sex differences in weight status in Black South

African adolescents. Biologically, energy needs differ for boys and girls and also in relation to rate of growth. Further, timing of sexual maturation differs by sex (26). Behavioral factors are also important in explaining the sex differences: boys are generally more physically active compared to girls especially during adolescence (12, 24, 27). Concerns about body image particularly among adolescent girls may lead to problematic eating behaviours such as irregular meal patterns which may result in increased weight gain (28). Differential problematic eating behaviours by sex have been reported among youth in South Africa (29). There was significant correlation between age and pubertal development, though there was no collinearity. This may indicate some attenuation of effect of each of these variables on weight status and central obesity.

The household level predictors of weight status and central obesity observed in this study include household head's highest education level, food security status and SES. While education level of the mother did not matter, education level of the household head was significantly associated with weight status and risk for metabolic disease. Education may affect nutritional status through knowledge of proper diet and of the harmful effects of overnutrition. Education level may also affect the income levels hence effects on diet and sedentary lifestyle. In this study, a little education was protective across the various measures of weight status and central obesity while education level that would substantially affect SES in the study community (completed secondary and tertiary education) was not significantly associated though it tended towards being positively associated with obesity. There seems therefore to be a counter-factual effect; while on one side education is protective, it also leads to higher BMI and central obesity. This possible counter-factual effect may be the reason why there was no association at higher levels of education. Additionally, there was a significant correlation between household head's education level and SES (though no significant collinearity) that may indicate attenuation of each of these factors in the overall effect.

Available literature on the association between food (in)security and childhood/adolescent overweight/obesity is generally conflicting (30, 31). In high income countries, food insecurity is often associated with childhood/adolescent overweight/obesity (30), because the poor may opt for the cheaper energy dense processed foods (32). However, some studies have indicated otherwise (31). Similarly, in LMICs, though limited literature exists, some studies have found a positive association between food insecurity and overweight/obesity and others otherwise (30). The study area, being a former homeland has low local food production. Food security may therefore relate strongly to ability to afford purchased (processed) food.

The relationship between SES and obesity varies across different countries depending on economic development (33). The direct relationship documented in this study is in keeping with several other studies in LMICs (8, 25, 33), but contradicts findings in high income countries (33). However, even in the high income countries such as the United States, the reverse association between SES and overnutrition is said to be weakening over time (34). Further, the association is population specific; for example, a direct relationship has been found among African-American children and adolescents, and a reverse association among the Whites in the US (34). Similar population-specific variations have been observed in other settings (35). Though South Africa is classified as a middle income country, there is high intra country inequality with regards to income distribution, and high level of poverty in some regions (13). The study area is low-income, located in a province with one of the highest poverty rates in South Africa (13). The pathways through which SES is associated with overnutrition include through income, education and occupation, resulting in behaviours which influence the balance between energy intake, expenditure and metabolism (36). SES is associated with sedentary lifestyle. Results not shown indicate that while almost all (96%) of least poor households owned a TV, slightly below 50% of most poor households did. Again, while 35% of least poor households owned a car which is likely to reduce time spent walking, only 7% of most poor households did. SES and food security variables were significantly associated (though the

association was not significantly collinear). This may indicate attenuation of overall effect of each of these variables on child weight status and risk for metabolic disease.

The extensive labour migration to larger towns in the study area (14, 15) facilitates the transfer and introduction of urban practices to rural settings with consequent change in diet resulting in substitution of traditional foods with energy-dense processed foods as seen in some settings in South Africa (37). While the least poor may afford to purchase such foods, the most poor may not and may therefore rely on their limited farm products and wild foods. It's no surprise then that most poor households consumed vegetables, wild foods and the main staple (maize) more often than the least poor households. About similar findings were documented with regards to food insecure households. Least poor households consumed the more fatty animal products like red meat and chicken more often. On the other hand, most poor households more often consumed the less fatty fish, some types of which (e.g. hake) are often cheaper than other types of meat in South Africa. Consumption of animal products and energy dense foods has been associated with overweight/obesity in countries undergoing nutrition transition (1). It is unfortunate that, in low-income settings, those who are able to afford energy dense foods are also the ones likely to afford sedentary lifestyles. This leads to imbalance between the energy consumption and expenditure hence overweight/obesity.

The above explanations specifically those regarding the association between gender and SES and overweight/obesity were in part confirmed by a community advisory group in Agincourt during a feedback session. The group indicated that the reasons for the high overweight/obesity levels in children and adolescents were mainly due to westernisation; indicating that households especially those with working parents tend to employ house maids who do most of the household chores thus children spend a lot of time viewing television and do little active work. They also mentioned that junk food is sold near schools hence children/adolescents readily access it. With regard to gender,

they indicated that girls tend to be more physically inactive than boys; while boys play soccer after school, girls have little options for physical activity (Group discussion with Agincourt community advisory group, June 2008).

About 5% of the study participants were classified as underweight using the 5th percentile cut-off for BMI, 6% in boys and 4% in girls. However almost all of those underweight were in ages 10 and 11 and in pubertal stages 1 and 2 indicating that they were still growing. Exclusion of these children did only marginally alter results, thus they were maintained in the final analysis. This study did not address the association between weight status and central obesity and the more proximate determinants; i.e. imbalance between energy intake and expenditure such as dietary patterns and physical activity. However, there is little controversy concerning these factors. The study therefore focused on the more distal determinants which give rise to the imbalance and for which current evidence is more controversial. The study used assets index rather than the actual measure of income level, while studies particularly in the developed world such as the US often use the actual income level. Measurement of actual income level in the developing countries particularly sub-Saharan Africa may not be feasible and assets index, has been found to be a good proxy for the actual income and expenditure (21). Additionally, the study did not use an elaborate food security status assessment to categorise households into various food security categories such as the US Food Security Scale as used in other settings (30). However, our measure of food security status is well indicative but future studies could use more elaborate scales.

This study has described key predictors of adolescent weight status and risk for metabolic disease in contemporary rural South Africa. These findings indicate need for gender sensitive strategies in addressing the rising problem of child/adolescent obesity. Specifically, though studies on physical activity level among the adolescents may be necessary, the results, reinforced by the views of the community advisory group illustrated above (Group discussion with Agincourt community advisory

group, June 2008), indicate need for interventions to increase the activity level, particularly of adolescent girls and especially around the time of pubertal onset. Further, though research on dietary patterns may be needed, diet-related education may be worthwhile. This may focus on importance of consumption of vegetables and fruits and modest consumption of animal source fatty foods particularly in the higher SES households. There is a dearth of literature on the association between food (in)security and childhood/adolescent overweight/obesity, particularly in LMICs (30). Though this study gives an indication in a low-income setting within a middle income country, further studies in other settings are recommended. Understanding the factors associated with the rising problem of overweight/obesity in children/adolescents in LMICs is critical in curbing the epidemic. This is particularly important because childhood/adolescent overweight/obesity are the driving force for the paediatric metabolic syndrome which is increasingly becoming a major concern in the LMICs (22). Further, there is a link between childhood/adolescent overweight/obesity and adult obesity and health risks (3, 4). The importance of addressing childhood/adolescent overweight/obesity promptly given the rising burden of obesity related non-communicable diseases in LMICs (2) including in the study area (38) cannot be overemphasised.

Authors' Contributions

EWK-M: Design of the study, project management, training and supervising fieldworkers, data management including cleaning and analysis, writing of the manuscript

KK: Design of the study, overall project co-ordination, review of the manuscript and approval for submission

JMP: Design of the study, review of the manuscript and approval for submission

SMT: Design of the study, review of the manuscript and approval for submission

KK-G: Analytic guidance, review of the manuscript and approval for submission

SAN: Design of the study, overall project management, analytic guidance, review of the manuscript and approval for submission

Acknowledgements

We acknowledge funding from the National Research Foundation (NRF) and the Medical Research Council (MRC), South Africa. The Agincourt health and socio-demographic surveillance system is funded by the Wellcome Trust, UK (069683/Z/02/Z). Elizabeth Kimani-Murage has a PhD fellowship funded by the Flora and William Hewlett Foundation, USA, while Dr. Shane Norris is on a Wellcome Trust funded fellowship. We acknowledge logistical support from the MRC/Wits Rural Public Health and Health Transitions Research Unit (Agincourt) during data collection and from the African Population and Health Research Center, Kenya during preparation of this manuscript. We acknowledge Dr. Mark Collinson, Dr. Xavier Gomex & Prof David Dunger for their technical contribution during design of the study. We acknowledge the data collection team and the LinC office team at the MRC/Wits Rural Public Health and Health Transitions Research Unit (Agincourt) specifically Rhian Twine, Geoffrey Tibane and Audrey Khosa for their role in community mobilisation. We also acknowledge the training team and the data entry team from the Birth To Twenty program, University of the Witwatersrand, South Africa funded by the Wellcome Trust, UK (077210/Z/05/Z).

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Appendices

Appendix 1: Data collection tools

Agincourt Health and Population Unit
UNIVERSITY OF THE WITWATERSRAND
Child-Mother follow-up study

CHILD HEALTH & NUTRITIONAL STATUS QUESTIONNAIRE

GROWTH SURVEY ID | | | | | |

Mother/caregiver's age …… **Level of education……..**

Main Occupation ……

(INTERVIEW MOTHER OR PRIMARY CAREGIVER OF THE CHILD. IF NEITHER IS AVAILABLE, ASK WHEN THEY WILL BE AVAILABLE AND MAKE AN APPOINTMENT. IF NOT WITHIN STUDY PERIOD, INTERVIEW THE PERSON CURRENTLY RESPONSIBLE FOR CHILDCARE)

(CONFIRM IF RESPONDENT IS THE ONE WHO TOOK CHILD FOR MEASUREMENTS IN GROWTH SURVEY)

1.0 CHILD'S RESIDENCE DETAILS

			Skip to
1.1	Does the child still live in this household?	Yes 1 No 2	→ 2.0
1.2	Where is the child? **(CIRCLE ONE MOST APPROPRIATE ANSWER)** 1 Dead 3 Temporarily away 6 Other(specify……) 2 Migrated 4 Orphanage/children's home 8 Don't know		
1.3	When did the child die, or cease to live in this household? M M Y Y Y Y **IF CHILD IS DEAD, ASK '1.4, ELSE SKIP TO SECTION 2.0)**		
1.4	Could you please tell me what happened? **IF RESPONDENT INDICATES ILLNESS IN RELATION TO THE DEATH, PROBE** What was the nature of the illness? How long was the child ill? Was treatment sought? Where? …… ……		
1.5	**ASK IF THERE'S A DEATH CERTIFICATE AND RECORD CAUSE OF DEATH** Cause of death (From Death Certificate) …… **IF CHILD IS DEAD, END THE INTERVIEW POLITELY WITH THE RESPONDENT…COMFORT THE RESPONDENT AS NECESSARY….THEN SKIP TO 10.0**		

2.0 RESPONDENT'S DETAILS

			Skip to
2.1	RELATIONSHIP TO CHILD, ASK, How are you related to the child? **(CIRCLE ONE MOST APPROPRIATE ANSWER)** 01 Biological mother 05 Step-mother 09 Aunt 02 Biological father 06 Step-father 10 Uncle 03 Grandmother 07 Elder sister 96 Other relative 04 Grandfather 08 Elder brother 98 Other (Specify……)		
2.2	Are you the primary caregiver of the child?	Yes 1 No 2	→ 2.4
2.3	IF NOT PRIMARY CAREGIVER, ASK, Who is the child's primary caregiver? 1 Biological mother 3 Step-mother 7 Aunt 2 Biological father 4 Step-father 8 Uncle 3 Grandmother 5 Elder sister 9 Other relative 4 Grandfather 6 Elder brother 10 Other (Specify……)		

2.4	For how long have you been taking care of the child? IF FOR MORE THAN ONE YEAR, RECORD IN YEARS, OTHERWISE RECORD MONTHS. IF SINCE BIRTH, WRITE 99	Number of years Number of months Since birth	
2.5	IF NOT THE MOTHER/PRIMARY CAREGIVER, CIRCLE REASON FOR NOT INTERVIWING MOTHER OR PRIMARY CAREGIVER 1 Caregiver away for a period longer than study period 2 Caregiver is never available during day time 3 Caregiver's where abouts are unknown 4 Caregiver is too ill 5 Other (specify……)		
3.0	**PERINATAL CARE SEEKING**		
	FW: IF RESPONDENT IS NOT THE MOTHER, SKIP TO 3.3		
3.1	At the time you were expecting the child, did you attend an antenatal clinic?	Yes 1 No 2 →	3.3
3.2	What useful information were you given during the antenatal clinics about caring for the child? **Probe** In terms of food/feeding? In terms of caring for the child?		
3.3	Was the child weighed at birth?	Yes 1 No 2 Don't know	3.5
3.4	How much did the child weigh at birth?	Grams Don't know 8	
	ASK TO SEE THE "ROAD TO HEALTH" CARD IF IT EXISTS & CHECK WEIGHT		
3.5	Weight from Road to Health Card	Grams Not Indicated 8 No card 9	
4.0	**CHILD'S NUTRITIONAL STATUS AND FEEDING PRACTICES**		
	....Now I would like us to discuss about the growth of your child and his/her feeding....		
4.1	In general, how is your child's growth compared to other children in the community? **Probe:** How is the child's growth compared to same time last year? …… ……		
4.2	Was the child ever breastfed? **CIRCLE THE APPROPRIATE RESPONSE**	Yes 1 No 2 → 4.6 Don't Know 8 → 4.7	
4.3	Is the child still breastfeeding? **CIRCLE THE APPROPRIATE RESPONSE**	Yes 1 → 4.5 No 2 Don't Know 8 → 4.7	
4.4	When did the child stop breastfeeding? **(MM/YYYY)** **IF CAN'T REMEMBER MONTH & YEAR, ASK;** For how long was the child breastfed? **CONVERT YEARS TO MONTHS AND RECORD IN MONTHS**	M M Y Y Y Y Months	

4.5	At what age was the child weaned (given other drinks/foods other than breast milk)?	Number of Months Don't know 8	4.7
4.6	Why was the child never breastfed? ……		
4.7	In general, how well is the child's feeding currently? ……		
4.8	How many meals does the child usually have/eat every day?	Number of meals	
4.9	Did the child take breakfast, lunch, supper yesterday? **(TICK IF CHILD HAD THE MEAL)**	Breakfast Lunch Supper	
4.10	**FW: Check 4.6 and ask 4.7 according to the meals ticked** What was the child fed on yesterday during: a) Breakfast …… b) Lunch …… c) Supper …… FW: IF CHILD MISSED ANY OF THE MAIN MEALS ABOVE, ASK WHY		
4.11	Please tell me, in the past three months, has there always been enough food for the child? **Probe** What challenges have you had in acquiring food for the child? Are there foods you would have wished to feed the child on but were not able? What foods? Why? …… ……		

5.0	**MOTHER/CAREGIVER'S HEALTH STATUS**		
	…Now I would like us to discuss about your health and care for the child when you are ill… ***FW: NOTE THAT THIS SECTION SHOULD BE ASKED ONLY TO THE CHILD'S MOTHER OR THE PRIMARY CAREGIVER. IF THE RESPONDENT IS NONE OF THE TWO, SKIP TO 6.0***		
No.	**Questions and Filters**	**Coding Categories**	**Skip to**
5.1	In general, what would you say about your health? ……		
5.2	Are you ill now or have you been ill in the last six months in a way that you could not run your daily activities normally?	Ill now 1 Not ill now but Ill in last 6 months 2 Not ill now or in last 6 months 3	→ 5.4
5.3	How was the illness like? **Probe:** What illness was it? How serious was the illness? How long did the illness last? ……		
5.4	When you are ill who normally takes care of the child? **Probe:** For example how does the illness affect how the child is cared for/ fed? ……		
5.5	How would you say your state of mind is currently? ……		

6.0	CHILD'S HEALTH STATUS & HEALTH SEEKING BEHAVIOUR & VACCINATION		
	…Now I would like us to discuss about the child's health status…		
No.	**Questions and Filters**	**Coding Categories**	**Skip to**
6.1	In general, what would you say about the child's health? ……		
6.2	Is the child ill now or has s/he been ill at any time in the last two weeks?	Yes 1 No 2 Don't Know 3	→ 6.4
6.3	Was the child sick any time in the last six months?	Yes 1 No 2 Don't Know 8	} 6.6
6.4	How is the illness like? (FW: IF THE CHILD IS NOT ILL CURRENTLY BUT WAS ILL IN LAST SIX MONTHS, ASK; When you recall the last illness that the child had, how was it?) **Probe:** What illness is/was it? How serious is/was the illness? How long has it lasted/did it last? How does it/did it affect the child's feeding/nutritional status? ……		
6.5	What has been/was done about the illness? **Probe:** What care has been was given to the child? Where was care sought? After how long? What affected careseeking decision? If care not sought, why? ……		
6.6	Is the Road-to-Health card available?	Yes 1 No 2	→ 6.8b
6.7	What is the colour of the card? **TICK AS APPROPRIATE**	White ☐ Yellow/Green ☐	
6.8	CHECK IF VACCINE BELOW WAS GIVEN FROM RTH CARD. TICK RESPECTIVE BOX IN 6.8a IF GIVEN & COUNT # OF DOSES. IF NO CARD OR NOT INDICATED ON CARD, ASK RESPONDENT AND TICK RESPECTIVE BOX & INDICATE # OF DOSES, IF DON'T KNOW #, WRITE 8.		

	6.8a FROM CARD		**6.8b FROM RESPONDENT**	
	Given?	# Doses	Given?	# Doses
	Y N		**Y N DK**	
BCG	☐☐	☐	☐☐☐	☐
Polio	☐☐	☐	☐☐☐	☐
DTP	☐☐	☐	☐☐☐	☐
Hib	☐☐	☐	☐☐☐	☐
Hepatitis B	☐☐	☐	☐☐☐	☐
Measles	☐☐	☐	☐☐☐	☐

'7.0	**CHILD'S PARENTAL SURVORSHIP AND CO-RESIDENCE WITH CHILD**	
'7.1	CHECK 2.1, IF NOT BIOLOGICAL MOTHER, ASK; Where is the mother? **(CIRCLE ONE MOST APPROPRIATE ANSWER)** 01 Lives in same HH but temporarily away 02 Lives in a different HH or village 03 Dead 03 Migrant worker 05 In school 06 Seperated/divorced with father 96 Other(Specify……..) 98 Don't know	
	IF DEAD, ASK '7.2 '7.3 & 7.4; ELSE SKIP TO '7.5	
7.2	When did the child's biological mother die? (YYYY/MM/DD) Y Y Y Y M M D D	
7.3	Could you tell me what happened? **IF RESPONDENT INDICATES ILLNESS, PROBE** What was the nature of the illness? How long was the illness? ……	
	ASK IF THERE'S A DEATH CERIFICATE AND RECORD CAUSE OF DEATH	
7.4	Cause of death (From Death Certificate)……	
7.5	CHECK 2.1; IF NOT BIOLOGICAL FATHER, ASK, Where is the father? **(CIRCLE ONE MOST APPROPRIATE ANSWER)** 01 Lives in same household (present or away) 02 Lives in a different HH or village 03 Dead 04 Migrant worker 05 Mother never married 06 Seperated/divorced with mother 96 Other(Specify……) 98 Don't know	
	IF DEAD, ASK '7.6, '7.7 & 7.8 ; ELSE SKIP TO '8.0	
7.6	When did the child's biological father die? (YYYY/MM/DD) Y Y Y Y M M D D	
7.7	Could you tell me what happened? **IF RESPONDENT INDICATES ILLNESS, PROBE** What was the nature of the illness? How long was the illness? ……	
	ASK IF THERE'S A DEATH CERIFICATE AND RECORD CAUSE OF DEATH	
7.8	Cause of death (From Death Certificate)……	
8.0	**AWARENESS OF CHILD'S HIV STATUS AND HIV CONFIMATORY TEST/VCT**	
	ASK IF THERE'S A DEATH CERIFICATE AND RECORD CAUSE OF DEATH ***….Knowing a child's HIV status is important in caring for the child….Some time last year, we (Agincourt Wits Unit) invited your child to participate in a growth survey camp in which we were also testing children aged less than five years for HIV…*** **IF RESPONDENT IS THE ONE WHO TOOK CHILD FOR TEST AND CHILD WAS POSITIVE, SKIP TO 8.3** **IF RESPONDENT IS NOT THE ONE WHO TOOK CHILD FOR TEST AND CHILD WAS POSITIVE, PROCEED WITH 8.1**	
8.1	Do you know the HIV status of the child?	Yes 1 No 2 → 9.0

8.2	What is the status?	Positive 1 Indeterminate 2 Negative 3 Don't know 8 Not willing to disclose 9	
8.3	We referred your child to a health facility/VCT for a confirmatory test …was the child taken for the test?	Yes 1 No 2	→ 8.5
8.4	What was the result of the test?	Positive 1 Indeterminate 2 Negative 3 Unwilling to disclose 4 Don't know/Not told 8	→ 9.0
8.5	Why was the test not done? ……		

IF THE CHILD IS POSITIVE AND RESPONDENT DOES NOT KNOW, DO NOT TELL THE RESPONDENT, BRING THE CASE FOR FURTHER DISCUSSION WITH THE PROJECT MANAGER

9.0 CHILD'S WEIGHT

WEIGH THE CHILD AND RECORD WEIGHT IN KG, TO NEAREST 1 DECIMAL PLACE

CHILD'S WEIGHT IN KGS ☐☐.☐

THANK THE RESPONDENT AND END THE INTERVIEW

IF CHILD IS POSITIVE AND RESPONDENT KNOWS, MAKE APPOINTMENT FOR INDEPTH INTERVIEW

IF CHILD IS POSITIVE AND RESPONDENT DOES'NT KNOW, MAKE APPOINTMENT FOR ANOTHER VISIT

10.0 GENERAL COMMENTS AND END OF INTERVIEW

10.1 RECORD ANY GENERAL COMMENTS ABOUT INTERVIEW

……
……
……
……
……
……
……
……
……
……

10.2 RESULT OF INTERVIEW
1–FULLY COMPLETED; 2–PARTIALLY COMPLETED; 3–CAREGIVER/PARENT REFUSED; 4–MIGRATED; 5–AWAY; 6–OTHER SPECIFY……)

10.3 FIELD WORKER'S CODE ☐☐☐☐

10.4 DATE INTERVIEW WAS COMPLETED

Y	Y	Y	Y	M	M	D	D

Agincourt Health and Population Unit

UNIVERSITY OF THE WITWATERSRAND

Child Health and Nutritional Status Follow-up Study

IN-DEPTH INTERVIEW GUIDE FOR MOTHERS/CAREGIVERS

INSTRUCTIONS TO THE FIELD WORKER

- Remind the respondent that you had made an appointment for a more detailed interview on their experience living with an HIV positive child.
- Confirm with the respondent if you can continue with the interview. If the respondent says no, please thank the respondent for their contributions and end the interview. If they say yes, proceed with the interview
- Also confirm with respondent if you can tape record the discussion. If respondent says no after adequate persuasion and reassurance, do not tape record, just take good notes of the interview.
- If they say yes, set the tape recorder and test to see it is working properly before proceeding with the interview.
- Make sure to often reassure the respondent about the confidentiality: that they will not be identified with the information generated in any reports or papers coming from the study, and that the tapes will be stored in safe cabinets and will only be accessible to the researchers in the study.
- Remind respondent that they are the experts in the discussion and that there is no right or wrong answer: that they should always feel free to say whatever they think or what their experiences have been. You should allow them to discuss an issue freely with little of your interruptions
- Always remember that this is not a questionnaire; it is only a guide; to guide you through the interview. So use the probes to guide the respondent to give information on that issue if the respondent has not already talked about the issue. If the respondent has already discussed the issue (even if in another question in this IDI guide), you do not have to repeat the question…you can skip.
- Remember that you are dealing with a vulnerable group, you need to be very courteous and also keen to note special needs in the respondent. If for example the respondent hesitates to answer a question, be courteous in persuading them to continue, if need be, you could also skip the question and move on to other questions that they may feel more comfortable answering and get back to the more difficult question when the respondent has fully opened up.
- If the respondent breaks down during the interview, give them time to recover, then move on slowly with the interview. If they cannot continue with the interview, end the interview.
- If you sense need for counseling, refer the respondent.

Growth Study ID [ ]

Mother/caregiver's age ……Relationship to child……

Level of education……..Main Occupation ……..

Ice Breaker Questions

Thank you very much again for allowing me to talk with you. Perhaps we can start by you telling me more about yourself and your family….

How are you and your family doing generally?

Main Study Questions

I take note that you are the mother/caregiver of a child who recently tested positive for HIV. This discussion may take you back to painful moments depending on what your experience living with an HIV positive child has been. Remember that if at any point in our discussion you feel uncomfortable about discussing a particular issue with me, you can let me know.

1) For how long have you known the HIV status of the child?

2) When you learnt of the HIV status of the child, how did you react? What thoughts came to your mind?

3) How helpful do you think it was to know your child's HIV status as far as care for the child is concerned?

Probe:

- How did it change your attitude towards caring for the child?

4) How does knowing your child's status affect how you prioritize care for the child relative to other children in the household?

Probe:

- For example, if there is no enough food in the household, would you rather feed the child first or feed other children first? Why?
- If the child is sick and also your other children are sick, would you rather take the child to the hospital or would you rather take the other children to seek care first?

5) How easy is it/was it to disclose the child's test results to other people?

Probe:

- Whom have you disclosed to?
- When you thought of disclosing the results, what were your greatest fears and concerns?
- When you disclosed the results, what happened? What were their reactions?

6) What is your experience generally caring for an HIV infected child?

Probe:

- What are your greatest challenges?
- In terms of food?
- In terms of health?

- Do you think the HIV status affects the child's behaviour, e.g. as far as feeding is concerned, relating to other children?

7) Has the child ever been exnposed to a traditional healer? Tell me more; What happened?

8) Is your child currently on antiretroviral treatment? Yes ☐ No ☐

If yes probe:
- How long has the child been on treatment?
- How has been the experience of the child being on the treatment? How is the compliance like? Any side effects?

If no probe:
- Why is the child not on anti-retroviral treatment? Have you ever sought advice on that?
- Also advise the respondent to visit clinic for advice on ARVs

9) What is your view about treatment, care and support for children living with HIV?

Probe:
- What are the benefits of seeking treatment for the child?
- What other kind of treatment/care support is your child already getting?
- What are the benefits of the services towards HIV infected children offered in this community?
- What barriers have you faced in seeking treatment, care and support for the child?

10) What support do you get from other people in caring for the child?

Probe:
- What support do you get from relatives and friends?
- What support do you get from the community?

11) What are your current thoughts about the child's life?

Probe:
- What are your current fears and concerns
- What are your aspirations for him/her?

12) Do you know your own HIV status? Please tell me more about that?
Probe:
- Did you do an HIV test the time you were pregnant with the child? What was the result?
- Have you done another test after the birth of the child? What was the result?

If they are HIV Positive Ask
- What are your experiences of living with HIV
- What challenges do you have?
- How are you coping with the situation of living with HIV you and the child?

If they are negative, advise them to go for test

13) What is you greatest fear?

14) What are your aspirations for the future?

Concluding Questions

I really appreciate all the information you have given me so far…

- Now I would like to ask you if you have any recommendations for example on how treatment, care and support for HIV infected children can be improved.

We have come to the end of the questions I had for you. Do you have any question you would like to ask me or to add?

***

Thank you very much for opening up to me concerning your experiences. The information you have shared with me is very valuable and will be used in improving care and support of children living with HIV and their mothers or caregivers.

***

Appendix 2: Ethical clearance certificates

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

Division of the Deputy Registrar (Research)

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)
R14/49 Kimani

CLEARANCE CERTIFICATE	**PROTOCOL NUMBER M070941**
PROJECT	Nutritional and health outcomes in children and Adolescents living in high HIV prevalence rural setting in South Afrca
INVESTIGATOR	E Kimani
DEPARTMENT	School of Public Health
DATE CONSIDERED	07.09.28
DECISION OF THE COMMITTEE*	APPROVED UNCONDITIONALLY

Unless otherwise specified this ethical clearance is valid for 5 years and may be renewed upon application.

DATE 07.11.12 **CHAIRPERSON** .....
(Professor P E Cleaton Jones)

*Guidelines for written 'informed consent' attached where applicable

cc: Supervisor : Drs K Khan/ S Norris

DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and **ONE COPY** returned to the Secretary at Room 10005, 10th Floor, Senate House, University.
I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee. **I agree to a completion of a yearly progress report.**

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

Division of the Deputy Registrar (Research)

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)
R14/49 Kimani

CLEARANCE CERTIFICATE	**PROTOCOL NUMBER M080330**
PROJECT	Health and Nutritional Outcomes of 1-5 year old children one year after A positive HIV test
INVESTIGATORS	Ms E Kimani
DEPARTMENT	School of Public Health
DATE CONSIDERED	08.03.25
DECISION OF THE COMMITTEE*	Approved unconditionally

Unless otherwise specified this ethical clearance is valid for 5 years and may be renewed upon application.

DATE 08.05.07 CHAIRPERSON .....
(Professor P E Cleaton Jones)

*Guidelines for written 'informed consent' attached where applicable

cc: Supervisor : Dr K Kahn

DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and ONE COPY returned to the Secretary at Room 10004, 10th Floor, Senate House, University.
I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee. I agree to a completion of a yearly progress report.

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

Division of the Deputy Registrar (Research)

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)
R14/49 Pettifor

CLEARANCE CERTIFICATE	**PROTOCOL NUMBER M070244**
PROJECT	Cross-Sectional Growth and Pubertal Study (0-20 years of age) in Agincourt Dikgale
INVESTIGATORS	Prof J Pettifor
DEPARTMENT	Paediatrics & Child Health
DATE CONSIDERED	07.03.02
DECISION OF THE COMMITTEE*	Approved unconditionally

Unless otherwise specified this ethical clearance is valid for 5 years and may be renewed upon application.

DATE 07.03.05 **CHAIRPERSON** .....
(Professors PE Cleaton-Jones, A Dhai, M Vorster, C Feldman, A Woodiwiss)

*Guidelines for written 'informed consent' attached where applicable

cc: Supervisor : Prof K Kahn

DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and **ONE COPY** returned to the Secretary at Room 10005, 10th Floor, Senate House, University.
I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee. **I agree to a completion of a yearly progress report.**

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

Division of the Deputy Registrar (Research)

COMMITTEE FOR RESEARCH ON HUMAN SUBJECTS (MEDICAL)
Ref: R14/49 Tollman

CLEARANCE CERTIFICATE PROTOCOL NUMBER M 960720

PROJECT	Investigating and responding to changes in the health and population dynamics of rural South Africans
INVESTIGATORS	Dr S Tollman
DEPARTMENT	HSDU/Community Health, Acornhoek
DATE CONSIDERED	970726

DECISION OF THE COMMITTEE *

Approved unconditionally
Generic Protocol - "Blanket approval"

DATE 970731

CHAIRMAN. .....(Professor P E Cleaton-Jones)

c c Supervisor: Dr S Tollman
Dept of Community Health, Medical School

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DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and ONE COPY returned to the Secretary at Room 10001, 10th Floor, Senate House, University.

I/we fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee.

DATE..7/8/96.....SIGNATURE .....

The University's United States Federal Wide Assurance Number is: SF,IORG0000862,IRB00001223.

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES