Child and adolescent obesity: Prevalence and risk factors in a rural South African population

Eva Craig B.Sc.

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Under the Supervision of Professor John J. Reilly and Dr Ruth M. Bland

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Abstract

Background

The World Health Organization estimates that 22 million children worldwide aged <5 years are overweight and highlights tackling childhood obesity as an urgent priority. Childhood obesity is rising to epidemic proportions in the developing world, reflecting changing physical activity levels and dietary intakes, adding a significant public health burden to countries where undernutrition remains common. Interventions to prevent childhood obesity have had disappointing results, because the science and aetiology of obesity is poorly understood and prevention programmes have not targeted appropriate behaviours nor adequately engaged communities being studied.

The origins of obesity appear simple – excess energy intake and/or low energy levels expended on physical activity, leading to chronic energy imbalance. However, the problem is more complex with underlying societal, behavioural and genetic causes of energy imbalance remaining unclear. Obesity is driven by individual, household and community factors: research to date has concentrated on individual factors with almost no significant focus on 'higher level' influences on obesity.

Findings from studies in developed countries are unlikely to be applicable to rural African settings where there is an increasing transition from a state of undernutrition to that of overnutrition. Few data exist on the prevalence of child and adolescent obesity from low and middle income countries like South Africa. This thesis aimed to determine the prevalence of overweight and obesity in children and adolescents (aged 7-15 years) within this population and to identify possible risk factors.

Participants and Methods

The study was cross-sectional and involved collecting primary data in local schools. A total of 1,519 subjects were recruited from three age groups (approximately 500 from each age group 7, 11 and 15 years). Participants were recruited from school grades 1, 5 and 9 corresponding to the ages 7, 11 and 15 years respectively. The study comprised two parts, a main cross-sectional study and a further study including a sub-sample of the participants. In the main cross-sectional study anthropometric measurements (height,

weight, mid-upper arm circumference and body fat) were performed on all the participants and a lifestyle questionnaire administered (questions related to water collection, travel to school, TV watching and sport participation). The study took place in a demographic surveillance area and data collected from participants was linked with their household/community data to allow analysis of variables associated with overweight/overfat status.

150 participants were randomly selected from the main study (50 from each age group 7, 11 and 15 years) and invited to take part in a sub-sample study which included objective measurement of physical activity (7 days accelerometry) and dietary assessment (2 x 24 hour multiple pass recall assessments) on each participant.

Main Findings

Prevalence of overweight and obesity was higher in girls than boys and was highest in the oldest age groups for females. Using the Cole/IOTF BMI for age reference combined overweight and obesity was 23% in grade 9 females compared to only 6% in boys in the same grade ($p<0.01$).

The lifestyle questionnaire revealed high levels of water collection, active commuting and TV watching (all ≥70%). Participation in sport (this included both organised sports such as football, netball etc and informal playground games) was low, with females in grade 9 reporting lowest levels (<30%).

Physical activity measured by accelerometry was a well accepted method and feasibility of using this measure within this population was good. The total volume of activity was higher than in age matched western sample but levels of moderate-vigorous physical activity (MVPA) were lower.

Dietary intake assessed by 24 hour recall revealed energy intake below recommended levels at all age groups however it was unclear whether this was due to misreporting or genuinely low intakes.

Analysis of the correlates of overweight and overfatness found sex and school grade to be the most consistently significant risk factors, being female and in school grade 9 (i.e. oldest age group) increased risk.

Mid-upper arm circumference (MUAC) cut-points for defining overweight and overfatness were proposed for age (5 - 9 and 10 - 14 years) and sex specific groups.

Conclusions

Analyses of both individual and 'higher level' influences on overweight and obesity show that sex and age are the most significant predictors of overweight and obesity in this population and females in the older age groups would be the population group most at risk of overweight and obesity. Given these findings females may be the most appropriate target for future interventions at an age before they become overweight.

Further studies would be required to identify any additional risk factors which may not have been analysed in the present study (i.e. sleep duration, psychological factors, pubertal status) but which may have a significant effect on risk of overweight and obesity.

The physical activity results from the present study (high volume, low intensity) raise the question as to whether current international physical activity guidelines (60 minutes MVPA per day) are appropriate for all children and adolescents globally and whether it is only intensity of physical activity which matters.

Additional dietary assessment, such as weighed records or direct observation, will be required to ascertain whether the results of the present study were attributable to misreporting or genuine low intakes.

This study also provided a novel proof of concept study for the potential use of MUAC as a proxy measure for overweight/overfatness.

In summary this study has defined the prevalence of overweight and obesity in children and adolescents in an under-researched rural South African population and highlights potential risk factors for the development of obesity in this specific population, presenting a basis on which to carry out future research for informing interventions.

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Publications, grants and awards

Published

Body fatness or anthropometry for assessment of unhealthy weight status? Comparison between methods in South African children and adolescents. Eva Craig, John Reilly, Ruth Bland, Public Health Nutrition, 2012, p1-9

Objectively measured physical activity levels of children and adolescents in rural South Africa: High volume at a low intensity. Eva Craig, Ruth Bland, John Reilly, Applied Physiology, Nutrition and Metabolism, 2013, 38(1), 81-84

Accepted for publication

Potential use of mid-upper arm circumference as a proxy for determining overweight or overfatness in children and adolescents Eva Craig, Ruth Bland, James Ndirangu, John Reilly, Archives of Disease in Childhood

Under Review

Risk factors for overweight and overfatness in rural South African children and adolescents, Eva Craig, John Reilly, Ruth Bland

Presented Abstracts

Commonwealth Association for Paediatric Gastroenterology and Nutrition (CAPGAN) 20-22 July 2011, London, UK

- Poster presentation - Prevalence of Over/Under-nutrition in Rural South African Children and Adolescents

- Oral Presentation - Physical Activity and Energy Intake in Rural South African Children and Adolescents

Royal College of Paediatrics and Child Health (RCPCH) May 2012, Glasgow, UK,

- Oral presentation - How best to assess unhealthy weight status?

American College of Sports Medicine (ACSM) May/June 2012 San Francisco, California

- Poster presentation - Comparison of accelerometer cut points in physical activity assessment of rural South African children and adolescents

Award

Commonwealth Association for Paediatric Gastroenterology and Nutrition (CAPGAN) Bhupinder Sandhu Prize for best oral presentation Dated 23 July 2011.

Grant

John Robertson Bequest Fund (provided funding, towards purchase of some accelerometer equipment)

Declaration Page

Author's Declaration

I declare that the work contained in this thesis is original, and is the work of one author, Eva Craig, except where otherwise stated. The information reported from other authors has been quoted with their name and source of publication. The relative contributions in terms of study design, data collection and analysis are shown below.

Signed

Name: Eva Craig

Date 6/09/2013

Author's role in this study

I was fully responsible for the design, implementation, analysis and writing up of this research study, which involved the following tasks:

Preparation

- Writing of initial ethics application, amendments and subsequent application for recertification with each subsequent year.
- Application for funding from other sources (John Robertson bequest fund, MacRobertson travelling scholarship).
- Project design.
- Planning of project timelines.
- Presentations to stakeholders including; The Africa Centre Community Advisory Board (CAB), South African Department of Education and local school principals to obtain permission to conduct the work in this area and within schools.

- Development of study protocols and procedures including: study information sheets, consent forms and questionnaires.

- Developing MS Access Database with the aid of the Africa Centre Database Scientist.

Recruitment and Fieldwork

- Project implementation and daily oversight of project management.

- Recruitment and interviewing of staff.

- Acquiring the necessary skills, ordering and purchasing equipment required for the fieldwork and training the appropriate fieldworkers on these techniques: including anthropometric measurements, accelerometer initialization, dietary assessment and use of accompanying software –ActigraphGT3X/Actilife for accelerometers and FoodFinder3 for dietary analysis.

- Oversight of all fieldwork: including arranging and conducting meetings with school principals and subsequently informing subjects of study, navigation and transport to schools and measurement of children in prevalence study. For the sub-sample this involved scheduling of timeline and transporting the nutritional assistant to schools, overseeing the explanation of accelerometry and conducting of dietary interviews.

- Problem solving and readjusting plans when the need arose, e.g., the impact of school strikes on the project.

- Quality control of all field work procedures.

Data management and analysis

- Input of all data into the appropriate programmes (MS Access database, MS Excel, EpiInfo, Anthroplus, FoodFinder3)

- Cleaning of all data for quality control purposes

- Analysis of data using Stata 11.0

Write up

- Yearly progress review

- Preparing and presenting presentations and posters for conferences

- Papers for publication (see Appendix 1)

- Writing of this thesis

Supervisor's Declaration

I certify that the work reported in this thesis has been performed by Eva Craig and that during the period of study she has fulfilled the conditions of the ordinances and regulations governing the Degree of Doctor of Philosophy

Signed Ruth M. Bland Ruth M. Bland

Date 6/09/2013

Signed John J Reilly John J. Reilly

Date 6/09/2013

Glossary

Acronyms/Abbreviations

AACE - American Association of Clinical Endocrinologists

ACDIS - Africa Centre Demographic Information System

AUC - Area under the curve

BIA - Bio-impedance analysis

BMI - Body mass index

BSID - Bounded Structure Identifier

CDC - Centers for Disease Control and Prevention

CSA - Computer Science and Applications

CVD - Cardiovascular disease

DEXA - Dual energy x-ray absorptiometry

DLW - Doubly labelled water

DSA - Demographic Surveillance Area

EGIR - European Group for the study of Insulin Resistance

GIS - Geographic Information System

HHID - Household Identifier

IDF - International Diabetes Federation

IOTF - International Obesity Task Force

IQR - Interquartile range

LO - Life Orientation

LPA - Light intensity physical activity

MC4R - Melanocortin 4 receptor

MET - Metabolic equivalent of task

MRI - Magnetic resonance imaging

MUAC - Mid-upper arm circumference

MVPA - Moderate - vigorous intensity physical activity

NCD - Non-communicable diseases

NHANES - National Health and Nutrition Examination Survey

OOP - Optimal operating point

ROC - Receiver operating characteristics

SD - Standard Deviation

SED - Sedentary behaviour

SFT - Skinfold thickness

TV - Television

US - United States of America

WC - Waist circumference

WHO World Health Organization

Definitions

Africa Centre for Health and Population studies – A centre for population based research located in the Umkhanyakude district of KwaZulu Natal, South Africa. The mission of the centre is: to conduct policy relevant health and population research, in an ethical manner, in partnership with the community in which it works and to enhance the capacity of the people of sub-Saharan Africa to do research (see Chapter 4: Methods).

Demographic Surveillance Area (DSA) – A specific region where the resident population are under observation. In this instance the Africa Centre DSA is located near the market town of Mtubatuba in the Umkhanyakude district of KwaZulu-Natal, South Africa. The area is 438km^2 in size and includes a population of approximately 85 000 people who are members of approximately 11 000 households. Both household and individual level data are collected from individuals (see Chapter 4: Methods).

Geographic Information System (GIS) - a system designed to capture, store, manipulate, analyse, manage, and present all types of geographical data. In this instance the GIS is specific to the Africa Centre DSA (see Chapter 4: Methods).

KwaZulu Natal – One of the 7 provinces of South Africa (see Chapter 4:Methods)

"Children are the major repository of South Africa's potential human capital for the future. The fact that children are the workers, scientists, parents, leaders and civil society participants of tomorrow means that their survival, health, nutrition and educational progress are key issues for reconstruction and development today."

(Nelson Mandela, May 1996)

1 Child and adolescent overweight and obesity

This first chapter aims to give an introduction to the background of this thesis detailing current knowledge of overweight and obesity amongst children and adolescents, significant research gaps in the literature and the reasons for conducting the present study. The topics covered in this introduction will be based mainly on systematic reviews, with those themes which are not so relevant to the present study kept intentionally brief.

Following a short introduction, the chapter is divided into 6 sections:

i. Definitions of overweight and obesity

ii. Prevalence of overweight and obesity in children and adolescents

iii. Aetiology and risk factors of overweight and obesity

iv. Consequences of overweight and obesity

v. Summary of gaps in the current literature on overweight and obesity in children and adolescents

vi. Rationale for conducting the present study

Throughout this thesis the collective terms ‘children and adolescents’ or ‘young people’ will be used, however, when referring to specific age groups within these terms, those aged ≤10 years of age will be identified as children and those >10 - ≤18 years of age as adolescents (WHO, 2013a).

Obesity is one of the most serious public health challenges currently facing individuals, communities and governments throughout the world and the scale of it has reached epidemic proportions (Han et al., 2010, Wang and Lobstein, 2006). A recent paper published in the 2011 Lancet series on obesity projected adult obesity to increase by 65 million in the USA and 11 million in the UK by 2030 (Wang et al., 2011). In recent years the prevalence of this issue in children has also been increasing at an alarming rate (Strauss and Pollack, 2001, Wang and Lobstein, 2006, de Onis et al., 2010) and steadily catching up with the present burden in adults (WHO, 2011). However, a recent review found evidence that the increase is now levelling off in children (Rokholm et al., 2010, Stamatakis et al., 2010). Although this is a positive finding it does not necessarily signify the end of the epidemic and it should be understood that there is every possibility of further increases in obesity prevalence in children and adolescents (Rokholm et al., 2010).

The World Health Organization (WHO) recognises childhood obesity as one of the most serious public health challenges of the 21st century (WHO, 2011). Although often considered to be an issue primarily affecting high-income, developed countries, research has shown the obesity epidemic to be a global problem and its impact is increasingly evident in many low- and middle-income countries, particularly in urban settings (Swinburn et al., 2011). It is in these low- and middle-income countries that changes are now occurring faster than in high-income countries (Patton et al., 2012); some areas of Asia, North Africa and Latin America have a rate of change in overweight and obesity prevalence two to five times higher than in the United States (Popkin and Gordon-Larsen, 2004).

The majority of research to date has been conducted in adults and predominantly in high-income countries, therefore there is a substantial lack of data on the prevalence and risk factors of child and adolescent obesity from middle-income countries like South Africa (Wang and Lobstein, 2006, Patton et al., 2012).

Interventions to prevent childhood obesity have had disappointing results, because the science and aetiology of obesity is poorly understood and prevention programmes have not targeted appropriate behaviours nor adequately engaged communities being studied (Reilly, 2006b, Reilly et al., 2005, Reilly et al., 2007, Viner et al., 2012, Hall et al., 2011). For this reason there is an urgent need for further research to be conducted in order to inform the development of effective interventions (Swinburn et al., 2011, Catalano et al., 2012).

1.1 Definitions of overweight and obesity

If overweight and/or obesity are the outcome variable of interest in epidemiological studies it is important that an appropriate and widely accepted definition is used to allow accurate comparison between studies (Reilly 2005). Methods employed must be practical and easily carried out in both field and clinical settings in order to ensure they are widely useable.

A simple definition of overweight and obesity is an excess of body fat, at or above the point which is believed to increase mortality or morbidity risk (WHO, 2000). Body fat is an important part of an individual's body composition and is essential for life; however there is a healthy range within which this fat should be maintained in order to present the most favourable conditions for health. Where the proportion of an individual's body fat lies either side of these ranges, either too low or too high, this poses a potential for complications and health problems. The clinical importance of diagnosing body fat is being able to determine the level at which it may have a detrimental effect on the individual and also to examine the relationship between increase in body fat and the corresponding increase in relative risk of morbidity and mortality. For public health reasons it is essential that accurate methods are employed to establish this relationship and that widely acceptable and practical methods are available for diagnosis of the risk in both field and clinical settings.

It is possible to directly measure body fat using techniques such as magnetic resonance imaging (MRI) and dual energy x-ray absorptiometry (DEXA), however these methods are extremely expensive and therefore are impractical for habitual clinical and field use (Wells and Fewtrell, 2006). More indirect proxy measurements are therefore favoured given that they are relatively inexpensive, portable and easier to use in the field.

Body mass index (BMI) is one of the most commonly used proxy measures and section 1.1.1 explains its use and application in detail. A more comprehensive list of measures, including techniques which specifically identify fat mass and/or its distribution throughout the body, is provided in 'Chapter 3: Justification of Methods'.

1.1.1 BMI

The most common and widely used proxy measure for fatness is body mass index (BMI)**.** This involves measuring height and weight and then performing a calculation based on the two measures, weight (kg) divided by height (m)^2 giving a value displayed as (kg/m^2). Essentially this provides a height-adjusted measure of weight which can then be used to determine whether this weight is too high, too low or in the right category for the given height.

In adults (age ≥18 years) there are internationally classified common cut points used for defining overweight and obesity, these are ≥25kg/m^2 and ≥30kg/m^2 respectively (Cole et al., 2000, WHO, 2004, Chen and Wang, 2010)[1]

Given that children and adolescents are all at varying levels of development and are undergoing a period of rapid growth, adult BMI cut points are not applicable for those under 18 years of age and it is necessary for cut points to be both age- and sex-specific (Cole et al., 2000, Cole et al., 2007, de Onis et al., 2007). National and international cut points are available for child and adolescent BMI; they have been developed to track the ‘normal’ growth of a ‘healthy’ child and are equivalent to the adult BMI cut point at age 18 years. As childhood cut points are age- and sex-specific they are plotted on sex-specific centile charts. Centiles divide a reference set of data into 100 equal parts which are then grouped into sections/curves; commonly used section breaks are 5, 10, 50, 85, 95. These curves give an indication of ‘normal’ distribution and a clearer approximation of where the ‘average’ healthy person should aim to be; where 50 indicates average and those above and below indicate ‘higher than’ and ‘less than’ average respectively (for an example of this see Appendix 2 for WHO BMI-for-age percentile charts).

An alternative method of displaying measurements relative to a reference is use of a standard deviation score (also known as a z-score). This is an indication of how much and in which direction a measurement deviates from the population mean. These can be positive (above the mean) or negative (below the mean). Where the mean is denoted by a z-score of 0 (or more generally between -1 and +1) BMI z-scores of >+1SD and >+2SD indicate overweight and obesity respectively.

Two internationally recognised child-specific references are described below: International Obesity Task Force and World Health Organization.

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[1] There has been much debate over whether these cut points are applicable in Asian populations given that Asian adults appear to have a different association between BMI, body fat and health risk. In many cases individuals of Asian origin show increased risk to health at a lower BMI than the current international definition for overweight. This risk appears to vary from 22-25kg/m^2 for overweight and 26-31kg/m^2 for obesity therefore instead of devising new cut points several extra cut points were added in order to facilitate the use of BMI in Asian populations (additional cut points are 23, 27.5, 32.5 and 37.5 kg/m^2) (WHO, 2004, Chen and Wang, 2010)

International Obesity Task Force (IOTF) standard definition for child overweight and obesity

In 2000 the IOTF published a child-based reference specific to overweight and obesity. This was developed based on 6 large cross-sectional growth studies from Brazil, Great Britain, Hong Kong, Netherlands, Singapore and United States with a total sample size of 97,876 males and 94,851 females aged 0-25 years (Cole et al., 2000). The data from each country were used to draw centile curves which passed through the adult BMI cut off points of 25kg/m^2 and 30kg/m^2 at age 18 years.

World Health Organization (WHO) child growth standards

The WHO conducted a Multicentre Growth Reference Study (MGRS) including a longitudinal study of children from birth to 24 months and a cross-sectional study from 18 – 71 months. The study included 8,500 children from 6 countries; Brazil, Ghana, India, Norway, Oman and United States (de Onis et al., 2004a).The results from this study were used to develop a reference for healthy children up to 5 years of age, where breastfed infants were used as the standard model for growth and development.

More recently a further study was conducted to develop a reference for children aged 5 - 19 years (de Onis et al., 2007), which would be in agreement with the previously developed cut points for pre-school children (de Onis et al., 2004a) as well as the adult BMI cut points at age 18 years. In order to do this, data from the pre-school sample were merged with data from the 1977 National Centre for Health Statistics (NCHS)/WHO reference(WHO, 1986). This new reference fills the previous gap which existed in the growth curves and now enables interpretation of BMI across all age groups (WHO, 2007).

There is debate over which centile cut points are most appropriate for definition and diagnosis of overweight and obesity with various cut points in use across different references. The important issue is that the cut point chosen provides the best possible balance of sensitivity and specificity. A high specificity is generally regarded as more important than high sensitivity in a clinical setting in order to optimize classification of those who are overweight and obese, however, if a high specificity is applied care must be taken to ensure that prevalence is not underestimated (Reilly et al., 2010c, de Onis et al., 2007).

Use of international references is valuable in that it allows comparisons to be made between studies conducted in different countries. A recent systematic review compared the accuracy of national BMI reference data versus international IOTF BMI reference data for definition and diagnosis of high body fat and cardiometabolic risk (Reilly et al., 2010c). This review found no significant reason to favour use of the international IOTF reference, however, national reference data are not available in all countries and therefore where data are unavailable, international references are of great use and provide a means of making international comparisons.

A recent study looked at the association between international WHO cut offs for overweight and obesity and cardiometabolic risk (investigating factors such as hypertension, insulin, cholesterol and triglyceride levels). Results showed these cut offs correctly identified children at higher metabolic risk therefore increasing the validity and biological significance for their use (de Onis et al., 2013).

BMI can be regarded as a very useful and simple tool for epidemiology and clinical screening however, as it is simply a proxy measure it may well over- or underestimate both over- and undernutrition. For this reason it should not be considered diagnostic on its own but is of use for describing groups, populations and changes over time (Hall, 2006).

1.2 Prevalence of child and adolescent overweight and obesity

Here I will look at the extent of the problem on a worldwide scale, then its effect on developing countries and finally an insight into the epidemic from a South African perspective.

Given the rapid changes in prevalence experienced by many countries in recent years, it is important to highlight that when reporting on prevalence it is essential to take note of the definition used, the sample studied and the timing of data collection. Method of measurement, reference and cut point used can all significantly affect results as shown in Table 1-1.

Table 1-1 Example of variation in reported obesity prevalence when using different references (adapted from (Reilly, 2005a))

Sample	Prevalence (IOTF reference)	Prevalence (National reference)	Source
Leeds, England 1996-99 Age 7-11years	2% boys 4% girls	14% boys 12% girls [a]	(Rudolf et al., 2001)
Switzerland Late 1990s Age 6-12 years	3.8% boys 3.7% girls	7.6% boys 5.9% girls [b]	(Zimmermann et al., 2004)
[a] Relative to UK 1990 Reference [b] Relative to US/CDC Reference			

Despite the variation in definitions used and therefore differing prevalence estimates between studies there is little doubt that both child and adolescent overweight and obesity has increased over the last few decades. However, research has found emerging evidence of a levelling off in prevalence over recent years (Rokholm et al., 2010, Stamatakis et al., 2010), despite this, there are no signs of a reversal as such, levels are still unacceptably high and further research is urgently required.

1.2.1 Worldwide prevalence of child and adolescent overweight and obesity

Increases in the prevalence of overweight and obesity have been reported from as early as 1971 (Dehghan et al., 2005). In 2010 the WHO estimated the worldwide number of overweight children under the age of five, to be over 42 million, close to 35 million of whom were living in developing countries *(Method: estimate from BMI data, Definition: WHO Growth Standards overweight defined as >+1SD, equivalent to BMI 25kg/m^2 at age 19 years).*

Global estimates from the International Association for the Study of Obesity/International Obesity Task Force (IASO/IOTF) analysis in 2010 estimated that up to 200 million school-aged children are either overweight or obese, and of those, 40 - 50 million are classified as obese (IOTF, 2010)*(Method: estimate from BMI data, Definition: IOTF reference).* Figure 1-1 below presents data of childhood overweight from several different countries over the last 40 years and shows a clear increase over time.

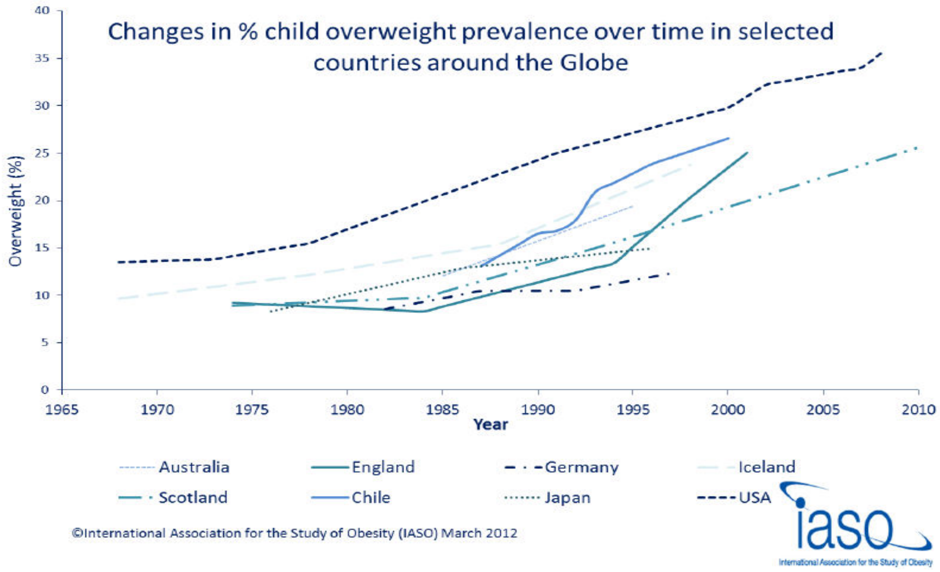

Figure 1-1 International Association for the Study of Obesity (IASO) data. Trends in childhood overweight from eight countries over four decades. (IASO, 2013a)

Rokholm et al conducted a systematic review of studies of trends in obesity prevalence from 1999, using data from 25 countries across Europe, Asia, Australia and North America. They found evidence that overall the prevalence of obesity is levelling off amongst children and adolescents whereas in adults the evidence suggested prevalence had stabilised in some areas but continues to increase in others (Rokholm et al., 2010). Unfortunately no data of African or South American origin were used in this analysis due to the fact that the studies available did not meet the inclusion criteria hence the authors call for further studies to be implemented in these areas (Rokholm et al., 2010). *(Method: BMI, Definition: IOTF reference although in some cases national reference data was used).*

A study carried out in England by Stamatakis et al also found that the trend for increasing overweight and obesity amongst children levelled off between 2002/3 and 2006/7 however disparities between socio-economic groups is widening, with children in the lowest socio-economic group not showing evidence of levelling off (Stamatakis et al., 2010).

Despite the possibility that the increase in obesity may have levelled off in some countries, as described above, the fact remains that even when conservative estimates of obesity are used at least 10 - 25% of the paediatric population in most developed countries is affected. There also appears to have been an overall shift in the perception of what is classified as a 'normal' body weight, due to the fact that even those children who are considered to be thin relative to the others are in fact fatter than they would have been in the past and also have a more central fat distribution (Reilly, 2005a).

Strauss et al conducted a study in the US investigating trends in childhood overweight and obesity over a 12 year period between 1986 - 1998 and found a staggering increase in prevalence of more than 120% in African Americans and Hispanics and over 50% in Non-Hispanic whites (Strauss and Pollack, 2001).

1.2.2 Prevalence of child and adolescent overweight and obesity in developing countries

The onset of this pandemic of obesity was initially among urban, middle-aged, adults in developed countries but it is now increasingly affecting semi-urban and rural areas and younger age groups and is also evident in developing countries (Wang and Lobstein, 2006).

Until recently the major issue facing developing countries was chronic undernutrition. Many developing countries are still battling with substantial problems relating to undernutrition and communicable diseases. However, the emerging epidemic of overnutrition and its accompanying non-communicable diseases are now presenting a double burden of disease in these countries with the two issues often found to be co-existing even within the same household, creating a complex issue for healthcare professionals and policymakers (Prentice, 2006, Popkin and Gordon-Larsen, 2004, Popkin, 2001, Boutayeb, 2006, Grijalva-Eternod et al., 2012, Kolcic, 2012, Kimani-Murage, 2013, Caballero, 2005).

Research by Prista et al showed there is still a considerable difference between developed and developing countries in the prevalence and trends of overweight and obesity (Prista et al., 2009), however, other researchers are less optimistic and believe the trend is the same and that developing countries are simply mirroring the same epidemic but are ten years or so behind (Armstrong et al., 2006).

Both under- and overnutrition are forms of malnutrition. The nutrition transition currently being experienced among children and adolescents is essentially an issue of the burden shifting from one form of malnutrition to the other, from a state of energy deficiency (undernutrition) to one of energy excess (overnutrition) (Moreno et al., 2006).

This disparity of weight status is often not only present in the wider community but within households. The number of dual burden households, those which contain both underweight and overweight or obese individuals, has increased rapidly (Popkin and Gordon-Larsen, 2004, Doak et al., 2000).

The international difference between the occurrence of this epidemic is that in the developed world the disadvantaged are believed to be at greatest risk whereas in the developing world, due to the common perception of obesity as desirable and a lack of knowledge of its detrimental effects, the wealthier are at greatest risk (Reilly, 2005a). However, this is not always the case and should not be taken to suggest that poorer children in developing countries are at low risk, as it is not simply income or education but many other risk factors that are involved and it is possible that dynamics may change over time (Monteiro et al., 2004).

Worryingly the fastest growth rates of overweight and obesity have been found in Africa, with reports showing that prevalence of overweight and obesity in children has more than doubled in the 20 years between 1990 and 2010 (de Onis and Blossner, 2000, de Onis et al., 2010). However there is a significant lack of data within this area. Of the 47 sub-saharan countries the International Association for the Study of Obesity (IASO) only has enough data to provide childhood overweight prevalence estimates for four countries (South Africa, Zimbabwe, Nigeria and Ethiopia) and even then some of the data are from almost 20 years ago (IASO, 2013b).

1.2.3 Prevalence of child and adolescent overweight and obesity in South Africa

South Africa is considered to be one of the countries in sub-saharan Africa undergoing rapid demographic and nutritional transition, associated with increased overweight and incidence of non-communicable diseases (NCDs) such as heart disease, stroke, type 2 diabetes and cancer (Steyn et al., 2005). These changes may be explained by rapid urbanisation associated with extreme changes in dietary intake, habitual physical activity and adoption of westernised lifestyles (Popkin, 2001).

The prevalence of adult overweight and obesity in South Africa has been reported as the highest in Africa with some studies showing rates which are comparable to those found in developed countries (Reddy et al., 2009). In South Africa, obesity was found to be three times as common in women as in men, 30% vs 9% respectively (Prentice, 2006) with similar findings in the most recently published age-adjusted prevalence estimates of adult obesity in South Africa - 21% (31% females and 9% males) (Alaba, 2013). A study carried out in 2003/2004 in the same demographic region as the present study found adult overweight and obesity prevalence of 58% and 32% respectively (Barnighausen et al., 2008).

Although social, political equality has greatly improved since the end of apartheid in 1994, South Africa is still a country with a diverse culture and population, as well as evidence of persisting disparities between ethnic groups (Magubane, 1994, Fiske, 2005, Kon and Lackan, 2008, Ayo-Yusuf et al., 2013). Some areas resemble that of a developing country whilst others are quite the opposite and are extremely developed, for this reason there are noticeable disparities in prevalence of overweight between populations from different geographical areas and ethnic backgrounds (Rossouw, 2012, Puoane et al., 2002, Kruger et al., 2005).

Age and gender differences are also well documented with strong age-dependent trends observed. A review by Rossouw et al highlights obesity in infancy as a significant issue, especially in rural disadvantaged areas, with overweight prevalence of approximately 20% in infants under 1 year old in rural areas of the Eastern Cape and KwaZulu-Natal (Smuts, 2008) and evidence of combined overweight and obesity rates as high as 50% for children aged 3 year old in rural Limpopo (Mamabolo et al., 2005). This is thought to be mainly a cultural issue with mothers perceiving larger babies to be healthier and so purposely overfeeding (Rossouw, 2012, Mamabolo et al., 2005). There then appears to be a levelling of prevalence until a second rebound occurs in mid - late childhood as adolescence approaches; prevalence at this stage has been found to be gender dependent with rates higher in girls than in boys (Kimani-Murage et al., 2010). The timing of this rebound is known to be an important determinant of obesity risk in later life, with an early age at adiposity rebound presenting an increased risk of both obesity and other chronic diseases; detrimental effects on aspects of metabolism such as glucose tolerance are also well documented (Cole, 2004, Crowther et al., 2008, Victora et al., 2008).

Table 1-2 shows the results of various nationally representative prevalence studies carried out in children and adolescents throughout South Africa. Only two of these national studies presented the results for each ethnic group. Given that the present study will focus on black children and adolescents, national prevalence data specifically of black children and adolescents are presented in Table 1-3.

The concept of 'benign' or 'healthy' obesity in rural South Africa is compounding the growing obesity epidemic and several studies have noted the positive and desirable perception of obesity (Mvo et al., 1999, Faber and Kruger, 2005, Puoane, 2005), as well as a lack of awareness of a healthy body size (Puoane et al., 2002). Many individuals have understandable concern about weight loss because of the association with HIV/AIDS and the focus of health services on undernutrition (personal communication, Stefanie Hyde) (Puoane and Hughes, 2005).

Statistics South Africa estimated the overall HIV prevalence rate in 2010 to be approximately 10.5%, with around 5.24 million individuals believed to be living with HIV at that point, while the new infections estimated for 2010 were 410,000 (40,000 of which were expected to be in children) (StatsSA, 2010).

Studies carried out across South Africa have shown clear evidence of the co-existing burden of underweight and overweight within the same household (Rossouw, 2012, Kimani-Murage, 2013). In a study of young children in a rural area of the Limpopo province, 31% of those classified as underweight were found to have an overweight mother or caregiver (Steyn, 1994). In a similar study conducted in the rural North West Province nearly 50% of mothers and/or caregivers of stunted and underweight children were found to be overweight (Steyn et al., 2005).

A more detailed description of South African studies can be found in 'Chapter 5: Prevalence of overweight and obesity'.

Table 1-2 Nationally representative studies of overweight/obesity prevalence in South African children and adolescents. (Adapted from (Rossouw, 2012))

Authors	Year study conducted	Study sample N	Study sample Age (years)	Anthropometric reference	Prevalence
Dept of Health (Department of Health, 1994)	1994	24,391	8 - 11	BMI-for-age (IOTF) BMI-for-age (WHO)	Overweight 1.2% Obese 0.2%
Steyn/ Labadarios (Labadarios et al., 2005, Steyn et al., 2005)	1999	2,894	1 - 9	BMI-for-age (IOTF)	Overweight: Total: 12.1% Rural:11.6% Urban: 12.5% Obese: Total: 5% Rural: 3.7% Urban: 6.1%
Labadarios (Labadarios, 2008)	2005	2894	1 - 9	BMI-for-age (IOTF)	Overweight 10% Obese 4%
Reddy (Reddy, 2010)	2008	10,270	14 - 19	BMI-for-age (Cole/IOTF)	Overweight 19.7% Obese 5.3%
Reddy (Reddy et al., 2009)	2002	9,224	13 - 19	BMI-for-age (Cole/IOTF)	Overweight: Total 6.9% Boys 6.9% Girls 4.5% Obese: Total 4% Boys2.2% Girls 5.3%
Armstrong (Armstrong et al., 2006)	2001-2004	10,195	6 - 13	BMI-for-age (Cole/IOTF)	Overweight Boys 10.8% Girls 13% Obese Boys 3.2% Girls 4.9%

Table 1-3 National overweight and obesity prevalence data specifically for black South African children and adolescents. (Adapted from (Rossouw, 2012))

Authors	Year study conducted	Age (years)	Anthropometric Reference	Overweight %		Obesity %	
				Boys	Girls	Boys	Girls
(Armstrong et al., 2006)	2001-2004	6 - 13	BMI-for-age (Cole/IOTF)	7.6	12.3	2.1	4.7
(Reddy et al., 2009)	2002	13 - 19	BMI-for-age (Cole/IOTF)	5.2	25.1	1.9	5.3

1.3 Aetiology and risk factors of overweight/obesity

Overweight and obesity could simply be described as the result of an energy imbalance (as shown in Figure 1.2) caused by excess energy intake and/or low levels of energy expended on physical activity. A small level of energy imbalance is perfectly normal in any individual as a small positive energy balance is necessary for growth. However, prolonged periods of excess positive energy balance, above the levels required for growth, can result in weight gain (Wiskin et al., 2011, Hall et al., 2011). Due to the basic aetiology of the condition, factors which are consistently highlighted in reviews of this subject are often those directly related to energy balance such as diet, physical activity and sedentary behaviour (Parsons et al., 1999, Rauner et al., 2013, Wareham et al., 2005). However, obesity is a complex and multifactorial condition which may be determined by a combination of individual, household or community level factors (Swinburn et al., 2011, Reilly, 2005b, Kimani-Murage et al., 2011). Despite this, research to date has concentrated on individual factors with very little evidence on 'higher level' influences on obesity (Davison and Birch, 2001, Birch and Davison, 2001). In order to fully understand the aetiology of this condition it is essential that future studies investigating risk use ecological models and conduct multilevel analyses (Kruger et al., 2006, Kimani-Murage et al., 2011).

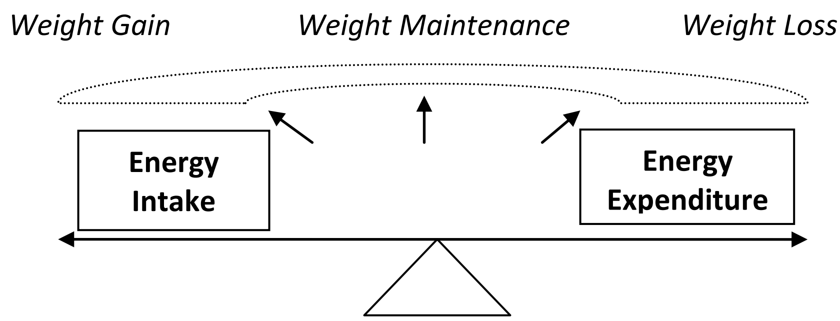

Figure 1-2 Energy Balance Equation

The aetiology of obesity in childhood is an extremely complex issue which has previously been referred to as ‘finding the needle in a haystack’ (Reilly et al., 2007). As mentioned earlier the complexity of childhood obesity arises from the fact that there are many factors which can play a part in the aetiology of this problem. A full description of all possible risk factors is beyond the scope of this thesis and here the focus is placed on factors most commonly reported by systematic reviews.

A recent review of systematic reviews investigating early life determinants of overweight and obesity found maternal smoking, breastfeeding, infant size/growth, short sleep duration and television to be the factors supported by good quality reviews (Monasta et al., 2010). A systematic review and meta-analyses of risk factors identifiable in infancy also reported maternal overweight and high infant birth weight or rapid weight gain during the first year of life as significant risk factors, while breastfeeding decreased odds of overweight by 15% and maternal smoking increased odds by 47% (Weng et al., 2012).

Studies included in the above reviews were predominantly conducted in developed countries. One review was found which focused specifically on developing countries, however, due to the lack of studies in developing countries they actually also included key studies from developed countries and highlighted the urgent need for further studies in developing countries (Yang and Huffman, 2013). The results of this review reiterated important risk factors as low birth weight and rapid weight gain in the first two years of life, as well as indicating breastfeeding may provide a protective effect. Additional findings included poor pre-natal diet with regards to protein, energy and micronutrients, as well as high protein intake during early childhood as risk factors for later obesity and evidence that delaying introduction of solid foods until six months may have a protective effect (Yang and Huffman, 2013). Several other reviews also support the concept of a protective effect of breastfeeding, the importance of delaying weaning until six months and monitoring of the macronutrient composition of foods introduced at weaning (Robinson and Fall, 2012, Pearce and Langley-Evans, 2013). However other studies have found conflicting evidence and continue to debate whether a strong link exists between breastfeeding and long term weight status (Cope and Allison, 2008, Martin et al., 2013, Brion et al., 2011). One recent study aimed to investigate the association of breastfeeding with blood pressure, BMI and IQ and compared results between high- and low - middle income cohorts (Brion et al., 2011); results showed an association between breastfeeding and lower blood pressure, lower BMI and higher IQ in the high income cohort. However, no strong association was found between breastfeeding and blood pressure or BMI in the low - middle income cohort, although the strong association with higher IQ remained (Brion et al., 2011). Inconsistency in results begs the question as to whether a consensus will ever be reached on the association between breastfeeding and weight status (Beyerlein and von Kries, 2011).

Previous research has also found that disparities in obesity risk exist between individuals of different ethnicities, as well as between the sexes and this will be discussed in sections 1.3.7 and 1.3.8 respectively (Taveras et al., 2010, Nindl et al., 2002, Shaw et al., 2007, Caprio et al., 2008).

1.3.1 Effect of dietary intake on overweight and obesity risk

The Oxford Dictionary definition of diet is ‘the kinds of food that a person, animal, or community habitually eats’. In recent years the modern diet has changed in a number of ways, a shift which is commonly referred to as the nutrition transition (Popkin, 2001). This shift included increased intake of processed foods, edible oils, sugar sweetened beverages and frequent consumption of pre-prepared foods outside the home (Popkin et al., 2012, Reilly et al., 2005). Previously associated with Western cultures and developed countries this transition is increasingly being seen in low income countries (Popkin et al., 2012).

It is not only the composition of foods which has changed but also the quantity consumed. In a US study of portion sizes of fast foods conducted between 1977 and 1996 it was found that portion size increased for all categories except pizza (Nielsen and Popkin, 2003). The mean energy intake and portion size of soft drinks increased by mean 49 kcal (13.1 to 19.9 fl oz [387.4 to 588.4 ml]), hamburgers by 97 kcal (5.7 to 7.0 oz [161.6 to 198.4 g]) and french fries by 68 kcal (3.1 to 3.6 oz [87.9 to 102.1g]) (Nielsen and Popkin, 2003). Another study investigating US portion sizes, found most marketplace portions to exceed standard serving sizes by at least a factor of two and sometimes eightfold. Portions offered by fast-food chains, for example, are often two to five times larger than the original size (Young and Nestle, 2003). These results suggest the need for greater emphasis on the relationship of portion size to energy intake as a factor in weight maintenance.

Other factors influencing dietary intake are increased availability and access to fast food as well as influences of the media such as advertisements during children's television programmes (Tanner, 2010, Sousa, 2009).

Since 2001, WHO guidelines recommend exclusive breastfeeding for the first 6 months of life and continued breastfeeding up until 2 years of age in combination with solid foods. As discussed previously in section 1.3, infant feeding is believed to be an important factor in obesity risk and one which is well documented in systematic reviews (Monasta et al., 2010, Owen et al., 2005, Weng et al., 2012, Yang and Huffman, 2013, Robinson and Fall, 2012), however, as described in the introduction to this section debate remains whether breastfeeding has a protective effect or whether this association is affected by other confounding factors such as socioeconomics (Brion et al., 2011, Martin et al., 2013). Further studies are required in developing countries to determine whether a relationship between breastfeeding and weight status is present in these areas (Yang and Huffman, 2013, Brion et al., 2011). A relationship has also been found between risk of obesity and both time of weaning and composition of foods consumed during this stage, where early introduction of solid foods and high intake of protein rich foods (especially dairy protein) are found to pose an increased risk (Robinson and Fall, 2012, Pearce and Langley-Evans, 2013, Weng et al., 2012, Yang and Huffman, 2013).

1.3.2 Effect of physical activity on overweight and obesity risk

Physical activity can be defined as any bodily movement produced by the skeletal muscle which requires energy expenditure (Caspersen et al., 1985). Physical activity should not be confused with exercise, which is a subset of physical activity in which the individual performs a structured, planned period of movement with the aim of improving or maintaining physical fitness.

There are different constructs which may be measured when assessing physical activity; this may be the total volume of physical activity or the cumulated volume of different intensities of physical activity i.e. light, moderate or vigorous (the definition of these intensities is shown in Table 1-4). There is considerable debate regarding whether total volume or intensity is more important when determining health benefits or relationship with obesity causation and maintenance and a general consensus that further research is needed (Laursen et al., 2012, Steinbeck, 2001, Shephard, 2001, Churilla and Fitzhugh, 2012, Woodcock et al., 2011, Janssen and Leblanc, 2010, Warburton et al., 2010, Jimenez-Pavon et al., 2009, Ekelund et al., 2012).

There are substantial gaps in the worldwide data available on physical activity, with data from low and middle income countries in Africa and Central Asia almost non-existent (Hallal et al., 2012).

Table 1-4 Definition of different exercise intensities by objective, subjective and descriptive measures. (Taken from position statement on physical activity and exercise intensity terminology (Norton et al., 2010))

Intensity category	Objective measures	Subjective measures	Descriptive measures
SEDENTARY	< 1.6 METs < 40% HR_{max} < 20% HRR < 20% VO_{2max}	RPE (C): < 8 RPE (C-R): < 1	• activities that usually involve sitting or lying and that have little additional movement and a low energy requirement
LIGHT	1.6 < 3 METs 40 < 55% HR_{max} 20 < 40% HRR 20 < 40% VO_{2max}	RPE (C): 8-10 RPE (C-R): 1-2	• an aerobic activity that does not cause a noticeable change in breathing rate • an intensity that can be sustained for at least 60 minutes
MODERATE	3 < 6 METs 55 < 70% HR_{max} 40 < 60% HRR 40 < 60% VO_{2max}	RPE (C): 11-13 RPE (C-R): 3-4	• an aerobic activity that is able to be conducted whilst maintaining a conversation uninterupted • an intensity that may last between 30 and 60 minutes
VIGOROUS	6 < 9 METs 70 < 90% HR_{max} 60 < 85% HRR 60 < 85% VO_{2max}	RPE (C): 14-16 RPE (C-R): 5-6	• an aerobic activity in which a conversation generally cannot be maintained uninterupted • an intensity that may last up to about 30 minutes
HIGH	≥ 9 METs ≥ 90% HR_{max} ≥ 85% HRR ≥ 85% VO_{2max}	RPE (C): ≥ 17 RPE (C-R): ≥ 7	• an intensity that generally cannot be sustained for longer than about 10 minutes

MET= Metabolic Equivalent, HRmax = Maximum Heart Rate, VO_{2max}= Maximal Oxygen Uptake, RPE= Rate of perceived exertion

Categories of exercise intensity and the subjective and objective measures [both absolute and relative] accompanying each category. The relative intensity measures such as %HR_{max}, %HRR[heartratereserve=HR_{max} −resting HR]and%VO_{2max} [maximal oxygen uptake] will not always correspond to the same RPE among individuals nor will the ability of clients to exercise for a specific duration at each intensity, since this varies depending on training status and other personal characteristics. Subjective measures are from Borg's RPE scales where C=category scale[6–20]and C-R=category-ratio scale[0–10] (Borg, 1998).

Current recommendations suggest that school-age children and youth (age 5 -17 years) should accumulate at least 60 minutes of moderate to vigorous intensity physical activity (MVPA) daily (WHO, 2010, WHO, 2011). This amount is deemed appropriate for both health and behavioural outcomes with benefits including musculoskeletal and cardiovascular health, as well as reduced adiposity, normotensive blood pressure and favourable lipid/lipoprotein levels (Strong et al., 2005).

There is significant evidence to support the belief that lack of physical activity contributes to increased risk of various non-communicable diseases such as coronary heart disease, type 2 diabetes and cancers of the breast and colon; estimates predict even a 25% decrease in physical inactivity could prevent 1.3 million deaths each year (Lee et al., 2012).

A systematic review of studies published since 2000 examined the relationship between physical activity, physical fitness and overweight/obesity in adolescents and found an inverse relationship between overweight/obesity and both physical fitness and physical activity (Rauner et al., 2013). However, this review highlighted the lack of studies in this area and the need for further studies aimed at determining the causal relationship between these factors. Of the 14 studies included in this review only one was from a developing country, again reiterating the need for studies to be conducted throughout the developing world (Rauner et al., 2013).

Another review examining associations between objectively measured habitual physical activity and adiposity in both children and adolescents found consistent evidence of negative associations between habitual physical activity and adiposity i.e. higher levels of physical activity provided protection against obesity (Jimenez-Pavon et al., 2009). The authors highlight the need for further longitudinal studies to increase the evidence base on this dose-response relationship (Jimenez-Pavon et al., 2009).

Previous studies investigating relationships between activity and obesity have often been inconclusive, partly because of crude physical activity measurement (Wareham et al., 2005).

Many challenges arise in the measurement of physical activity and reviews have found self-report methods to have low validity (correlation coefficent of 0.3-0.4 when compared to objective method) and high imprecision. Even objective methods such as accelerometry present challenges such as lack of standardised cut points for different intensities and, as yet, no definitive conclusion has been reached as to how cut points are affected by age (Ekelund et al., 2011). This is discussed further in 'Chapter 3 – Justification of methods'.

Based on recent results from self-report studies approximately 30 - 40% of children worldwide are sufficiently physically active, however, due to the challenges with objective measurement and the lack of standardised thresholds for intensity, results from accelerometry studies range from 1-100% sufficiently active (Ekelund et al., 2011). There is an urgent need for an internationally standardised method of measuring physical activity objectively, in order to allow accurate measurement and comparison between studies, as well as enabling a true assessment of the scale of the problem (Ekelund et al., 2011). In recent years some studies have reported evidence of declines in the level of physical activity in children, both secular and age-related (Boreham and Riddoch, 2001, Goran et al., 1998, Basterfield et al., 2011a, Malina and Little, 2008, Kimm et al., 2002, Belanger et al., 2011, Sallis, 2000). This decline appears to be related to a number of areas, three of which are discussed below; active transport, physical education and organised sport. It should be noted that some literature casts doubt on secular trends and suggests that there may not necessarily be a decline (Ekelund et al., 2011).

Active transport

Active travel to school is associated with higher levels of objectively measured physical activity and may represent an important intervention area for increasing children's overall physical activity (Owen et al., 2012).

Black et al found evidence that walking as a means of transport is deteriorating in the UK and that between 1975/6 and 1989-1994, 5-10 year olds showed a decline in walking to school (from 71 to 62%) and a concurrent increase in travelling to school by car (from 15 to 28%)(Black et al., 2001). This was primarily attributed to an increase in parents' fear for their child's safety coupled with the change in perception of a 'walkable distance'. Where previously children would have walked several miles to get to school, a distance more than a short walk is now deemed too far (Black et al., 2001). One study of school children in the UK found that those living ≥2.5 miles from school reported distance to be their main barrier, with a one-mile increase in distance decreasing odds of active commuting by 70% (Nelson et al., 2008). Other factors which play a part in deterring active transport are inclement weather, traffic volume and crime levels (CDC, 2005). It is unclear whether these same issues may affect school travel in developing countries. The recent Lancet series on physical activity reported only on active transportation amongst adults and did not provide data on worldwide active transportation amongst children (Hallal et al., 2012). Reported levels of active transportation in adults were less than 5% in Australia, Switzerland and the USA, this study also highlighted the lack of data available from low-income countries (Hallal et al., 2012).

Following a review of trends in active school travel in primary children (PhD thesis, David McMinn, University of Strathclyde) it was found that few data are available from children in developing countries. The majority of the 57 studies reviewed had been conducted in UK, USA and Australia, no studies were found in sub-saharan Africa and therefore further research is warranted in this area (PhD thesis, David McMinn, University of Strathclyde).

Since the review mentioned above was carried out one study has now been published from sub-saharan Africa, a study which took place in Kenya. The study aimed to look at the effects of urbanisation on activity levels, with adolescents from an urban area compared to those from a rural area, 100% of the rural adolescents reported either walking (40%) or running (60%) to school, with some individuals covering in excess of 7km to reach school and 31% reporting it took over one hour to reach school. In contrast only 50% of urban adolescents actively commuted to school, with 41% and 9% walking and running respectively and all of these reported taking no longer than 30 minutes to reach school, the remaining 50% travelled to school by car (Ojiambo et al., 2012). Although this is a sub-saharan study it is not clear how these results would compare to South Africa given the differing levels of development between the two countries.

Physical education

Evidence suggests that physical education in schools is a crucial factor in developing physical skills, improving psychological wellbeing, social and cognitive development and learning healthy behaviours to be taken into adulthood (Bailey, 2006). Despite this evidence, school policies have changed, and in turn, time recommended for assignment to physical education (PE) on the school curriculum has reduced; the percentage of schools adhering even to these reduced recommendations is low (Marshall and Hardman, 2000). A systematic review carried out in five high income countries found physical activity during physical education classes has decreased since the 1990s (Knuth and Hallal, 2009). Globally only around 71% of PE is implemented in accordance with regulations. Throughout Europe there is a legal requirement for PE to feature on the curriculum with a time allocation of around 6-7%; however these requirements are not always implemented. When looking at other geographical regions the situation is considerably bleaker; in Africa and Asia PE has been found to be adequately implemented in only one quarter and one third of schools respectively (Marshall and Hardman, 2000, Hardman, 2005).

Across the continent of Africa many countries report lack of facilities and adequately trained staff, and physical education is often considered to be of little value, viewed as 'non-educational and a non-productive use of time' (Hardman, 2005). The situation in South Africa is of particular concern in that PE is no longer a subject on the curriculum and has been replaced by a new subject called Life Orientation (LO) (Department of Basic Education, 2003); a subject which focuses on the holistic development of individuals in terms of social, intellectual, emotional and physical growth but provides no necessity to take part in physical activity (Marshall and Hardman, 2000). There is ongoing debate as to the effectiveness of this new subject (Jacobs, 2011).

Organised sport

In the UK, there appears to be a trend towards a decline in the playing of organised sports (Allender et al., 2006). Physical factors reported to affect participation in sport were: having an unfit body, lacking confidence or core skills and fear of appearing masculine (Allender et al., 2006). Others barriers may include reduced access to sporting activities (cut backs in the education system have meant many extracurricular activities are no longer offered), increasing costs related to participation and a decline in parents acting as role models for participation in sport (Martin et al., 2005). In previous years there was a strong relationship between parents' physical activity and that of their child, however, an Australian study, showed this association to have all but disappeared over a 15 year period from 1985-1997 (Martin et al., 2005). There is a lack of evidence regarding the effect of this decline in sport participation and one recent systematic review found no evidence of studies which examined the effectiveness of interventions to increase sport participation highlighting the need for such research (Priest et al., 2008).

The picture is worse still in developing countries burdened with poverty, illiteracy and communicable disease where sport is perceived as a luxury and does not rank as a top priority in the government budget. There are few data available on levels of organised sport in developing countries however one older study found a ratio of 0.01% to 1% of the population in African developing countries taking part in sport (taken from a UNESCO questionnaire which was carried out by 16 African low income countries) compared to 20-25% in European countries (Souchaud, 1995).

However, a recent review claimed that available evidence does not indicate sport participation in youth has decreased in recent years (Ekelund et al., 2011); the same review also draws attention to the fact that there is a paucity of information on physical activity in youth, especially for those in low and middle income countries and this lack of data is hampering the ability to observe worldwide trends (Ekelund et al., 2011).

1.3.3 Effect of sedentary behaviours on overweight and obesity risk

Given the recent increase of research into the effects of sedentary behaviour (Tremblay et al., 2010) and the lack of a standard definition for this behaviour, in 2012 the Sedentary Behaviour Research Network (SBRN) published a definition which they suggest is used in all future research to increase transparency of results and allow comparisons to be made between studies (SBRN, 2012). 'Sedentary behaviour is, any waking behaviour, characterized by an energy expenditure $\leq$1.5 metabolic equivalent of task (MET) while in a sitting or reclining posture.'(SBRN, 2012). 'Sedentary' should not be confused with inactive which is defined as 'an individual performing insufficient amounts of MVPA (i.e., not meeting specified physical activity guidelines)' (SBRN, 2012).

The most common sedentary behaviours investigated when determining relationship with obesity are screen-based activities such as TV watching, as well as use of computers and gaming consoles. These will be discussed below along with another important sedentary behaviour - sleep duration.

A review investigating the relationship between sedentary behaviours and obesity development (Rey-Lopez et al., 2008) found sedentary behaviours to have a significant impact on risk of obesity development. The behaviours investigated in this review included TV watching as well as participation in other screen time activities such as gaming consoles and computer use and focussed on adiposity as the outcome. Another more recent systematic review of cross-sectional studies used weight as the outcome and also found sedentary behaviour to be positively associated with weight status in the majority of studies (7 out of 9) however two of the studies found no association and interestingly these were the only two which used an objective measure of physical activity as opposed to self-report. Therefore the authors suggest this could imply objective measures are required in order to accurately determine the relationship (Prentice-Dunn and Prentice-Dunn, 2012).

1.3.3.1 TV watching

As indicated above many studies have found an association between TV watching and increased risk of overweight and obesity. (Reilly et al., 2005, Tanner, 2010, Hancox et al., 2004, Burdette and Whitaker, 2005, Sousa, 2009, Robinson, 2001, Rey-Lopez et al., 2008). TV watching is known to be a risk factor of obesity not only due to its sedentary nature but also as a result of the increased exposure to 'junk food' advertising experienced when watching and the tendency to comfort eat during viewing (Utter, 2006).There is also evidence that satiety cues may be affected by the distraction of watching TV (Bellissimo et al., 2007).

In recent years, TV ownership has increased rapidly, especially in developing countries (Popkin and Gordon-Larsen, 2004); it is expected that this increase in ownership will be coupled with a substantial increase in time spent watching TV, however, there are limited data available from developing countries (Gomez et al., 2007). One cross-sectional study carried out in Colombian children and adolescents aged 5-12 years found 41.5% viewed television for less than two hours per day; 36.8% between 2 and 3.9 hours per day and 21.7% four or more hours per day. In this study those who watched more than 2 hours per day were more likely to be overweight than those reporting less than 2 hours per day (Gomez et al., 2007).

Results from a risk behaviour survey carried out in over 15,000 US adolescents found TV watching of greater than four hours per day (Eisenmann et al., 2002), despite the American Academy of Paediatrics recommendations that viewing should amount to no more than one or two hours per day for school-aged youth. Sedentary behaviour recommendations are also available from Australia and Canada. The Canadian guidelines for both children and adolescents aged 5-11 years and 12-17 years recommend limiting screen time to no more than two hours per day and limiting sedentary methods of transport, extended sitting and time spent indoors throughout the day (CSEP, 2011, Tremblay et al., 2011). Australian guidelines also recommend a maximum of 2 hours screen time per day in children and adolescents aged 5-18 years, but maintain that children under 2 years of age should have no screen time and children between 2-5 years of age should have screen time limited to less than one hour per day (Australian DoH, 2010).

It has been shown that US children aged 2-5 years now spend an average of more than 32 hours a week in front of a TV screen. Those aged 6-11 years spend a little less time, about 28 hours per week watching TV, partly due to the fact that they are more likely to be attending school for longer hours (McDonough, 2009).

Multiple ownership of TVs within households in the developed world has escalated (Jeffery and Utter, 2003). Studies in the developed world have also found that the number of children who have a TV in their room has increased and this has been shown to lead to an average increase of 38 minutes viewing per day (Wiecha et al., 2001). However TV ownership and levels of TV watching in developing countries is under researched and few data exist, especially from sub-saharan Africa.

1.3.3.2 Media and entertainment activities

Reviews have noted that participation in other screen time activities such as gaming consoles and computers has also increased (Prentice-Dunn and Prentice-Dunn, 2012, Rey-Lopez et al., 2008). The studies included in these reviews were mainly from developed countries including the USA, UK and mainland Europe, but some middle income countries such as Mexico, Brazil and China were included. None of the studies included had been conducted in Africa (Prentice-Dunn and Prentice-Dunn, 2012, Rey-Lopez et al., 2008).

Computer ownership in the US increased from 7.9% in 1984 to 36.6% in 1997 (Kominski, 1999) and statistics from the UK also demonstrate a rapid increase in ownership between 1998 and 2002 from 34%-54% (ONS, 2002). Levels of Internet access and use of gaming consoles is also now very high, with a reported average of 31 hours internet use per month for both boys and girls aged approximately 16 years and an average of 27 hours per month game playing in boys of the same age, with lower levels of four hours per month reported in girls (Van den Bulck, 2004). In conjunction with the already high levels of TV watching, these additional screen time activities amount to alarming quantities of overall screen time during a waking day. Data from low income countries is still sparse and given the increasing rate of development in these countries it is important further research is carried out to determine current levels and its impact on weight status within these countries. Debate remains as to whether sedentary behaviour actually displaces physical activity or whether it is obesogenic in its own right (Biddle et al., 2004b, Biddle et al., 2004a).

1.3.3.3 Sleep duration

Studies have reported a clear association between short sleep duration and increased weight gain and risk of obesity in children and adolescents (Sousa, 2009, Garaulet et al., 2011)with meta-analysis showing this risk to be more prominent in children compared to adults (OR of 1.89 vs 1.55 respectively) (Cappuccio et al., 2008). Again, the majority of data included in these studies were from individuals in the US or Western Europe; although there was one study from each of North Africa, Asia and South America but no data from children in sub-saharan Africa (Sousa, 2009, Garaulet et al., 2011, Cappuccio et al., 2008).

Sleep duration has been reported to play an important role in obesity development; children aged 30 months who slept for less than 10.9 hours were more likely to become obese before 7 years of age than those who slept more than 12 hours per day (Reilly et al., 2005).

Less sleep can affect hormonal balance (including appetite regulation) and cognitive function, as well as leading to more time awake for potential eating. In turn, the tiredness experienced the next day as a result of sleep deprivation may result in further comfort eating (Knutson et al., 2007, Dahl, 1996, Sadeh et al., 2003).

There are several aspects of physical activity and sedentary behaviour with which there is ongoing debate. These include: Does physical activity protect against obesity? Is sedentary behaviour obesogenic independent of physical activity? And is MVPA the construct of physical activity which matters most to later obesity risk? These issues will be addressed in ‘Chapter 6 – Lifestyle, physical activity and diet’ whilst discussing the results of the present study.

1.3.4 Effect of socio-economic status on overweight and obesity risk

There are noticeable socio-economic differences in risk of overweight and obesity between developed and developing countries. In most developed countries the poor are believed to be at greatest risk of overweight and obesity whereas in developing countries the rich appear to be at greatest risk (Farooqi and O'Rahilly, 2005, Clement et al., 2002a). A recent systematic review found low socio-economic status in children to increase risk of overweight and obesity in later life, however, all studies included in this review were from developed countries and it is unclear whether these results would also relate to developing countries (Tamayo et al., 2010). A review of adults in developing countries found that overweight is not necessarily always associated with a higher socio-economic status (SES) and as the country's gross national product (GNP) increases the risk of overweight shifts to those with a lower SES; this shift appears to occur at an earlier stage of economic development for women than it does for men (Monteiro et al., 2004). Although this review focussed on adults as opposed to young people it is interesting to note the association which was found (Monteiro et al., 2004). The most recently published South African study which aimed to investigate the effect of social determinants on the prevalence of adult obesity found living in a less deprived neighbourhood increased the risk (Alaba, 2013).

A large number of socio-economic factors have been found to have an important effect on risk of overweight and obesity. Several factors found in a previous South African study and which will also be investigated in the present study are: type of housing, type of toilet in the home, fuel used in cooking, presence of refrigerator or stove, presence of TV in the house, educational level of caregiver and maternal educational level (Steyn et al., 2005). Factors found to decrease risk of overweight were having an outside drop toilet, using paraffin as fuel for cooking, having no refrigerator, no stove and a mother with only primary education. On the other hand, factors associated with increased risk were living in a traditional or mud house and having a flush toilet (Steyn et al., 2005). Another study carried out on children in the Birth-to-Twenty study (Bt20) in urban South Africa examined at the effect of SES at birth on anthropometric outcome at age 7/8 years and found the variables which had a significant positive effect were ownership of a car, telephone, and having an inside flush toilet (Sheppard et al., 2009). A further study carried out on the same group of children at age 9/10 years explored the effect of SES on fat mass index, lean mass index and body mass index (Griffiths et al., 2008). Results showed that children in the highest SES tertile at age 9 or 10 years had an increased fat mass index compared to those in the lowest tertile. In this study, the results for black children revealed that SES both at birth and at ages 9 or 10 years accounted for 8% and 6% of the variance in FMI and BMI, respectively (Griffiths et al., 2008). The most recent Bt20 study published on this topic looked at longitudinal behaviours in adolescents aged 13, 15 and 17, with results showing that fridge ownership at birth, which was used as a marker of having a higher household disposable income, was positively associated with both BMI z-score and fat mass (Feeley et al., 2013).

1.3.5 Effect of maternal factors on overweight and obesity risk

As indicated in the introduction to this section (section 1.3), systematic reviews consistently report the significant impact of maternal factors in the development of overweight and obesity in their offspring.

The Barker Hypothesis was a theory first proposed by David Barker (Barker, 1992); after much research and consistency in study results it was named the Barker Hypothesis in 1995 - also known as the thrifty phenotype (Paneth and Susser, 1995). This hypothesis is based on the understanding that conditions experienced during pregnancy lead to early foetal programming and, in turn, can have long term effects on the health of the child with regards to chronic diseases such as coronary heart disease, type 2 diabetes and obesity (Barker, 2004b, Barker, 2004a).

A prime example to support this hypothesis is that of the Dutch hunger famine of 1945 (during World War II) when there was a period of extreme food shortage in an area of the Netherlands for around 6 months. Children born to women who had been pregnant during this time of famine showed signs of restricted intrauterine growth at birth and subsequently had an increased risk of conditions such as coronary heart disease and obesity in later life (Roseboom et al., 2006).

One of the mechanisms for this is believed to be as a result of ‘early programming’ where the foetus makes metabolic adaptations during the gestational period which prepare the body for similar conditions after birth. However, when conditions during childhood or adulthood are in fact significantly different to those experienced in-utero this early programming becomes inappropriate and increases susceptibility to adverse health effects (Wells, 2007). One example of such a change is the nutrition transition currently being experienced in many low- and middle-income countries where diets consisting of mainly unrefined foods, high fibre, low fat foods are changing to western diets of highly processed food, high in fat, edible oils and sugar sweetened beverages (Popkin, 2001, Popkin and Gordon-Larsen, 2004, Popkin et al., 2012).

One study investigating indices of maternal and child outcome examined the results of prospective cohort studies in five countries including South Africa and found an increased risk of higher BMI, blood glucose concentrations and blood pressure if individuals birth weight was low, mothers height was below average and if there was evidence of intrauterine growth restriction of offspring (Victora et al., 2008).

Several other South African studies have explored the effects of maternal undernutrition on the health of the child in later life and have found an association with significant increases in mortality and overall disease (Black et al., 2008). Metabolic effects include elevated blood pressure, impaired glucose tolerance and beta cell function, insulin resistance and dyslipidaemia (Crowther et al., 2008, Levitt, 2006). There is significant evidence to suggest that susceptibility to obesity may be increased and there are effects on body composition such as low birth weight being associated with reduced lean tissue mass and therefore increased body fat content, as well as an increase in central adiposity which is believed to be related to risk of cardiovascular disease and diabetes (Levitt, 2006, Cameron et al., 2003). The timing of catch up growth in early life, following a low birth weight or evidence of restricted intrauterine growth is also crucial in determining later metabolic risks (Levitt, 2006).

Given the significant effects maternal nutrition is believed to have on a child's future health it has been suggested that the most effective solution to avoiding various childhood morbidities would be to target interventions promoting healthy diet, lifestyle and body composition at women in the pre-pregnancy state in order to ensure optimum benefit to both mother and child, a strategy that might be most effective in low and middle income countries currently undergoing the socio-economic transition (Hanson et al., 2012).

Other maternal factors consistently shown by systematic reviews to increase risk of obesity in offspring are maternal overweight, smoking and presence of type 2 diabetes (Reilly et al., 2005, Toschke et al., 2002, Oken et al., 2008, Monasta et al., 2010). These studies were conducted predominantly in western countries and therefore their generalisability to developing countries is unknown.

1.3.6 Effect of genetics on overweight and obesity risk

A recent systematic review found genetics to have a stronger effect than environment on childhood obesity, however, the majority of studies reviewed were conducted amongst Caucasians and there is a call for further research to be conducted in non Caucasian populations where, at present, there are a lack of data (Silventoinen et al., 2010).

In a small minority of cases, obesity may be caused by a single gene mutation significantly affecting an individual's metabolism, this is known as monogenetic and examples of this are Bardet Beidl, Cohen's and Prader-Willi syndromes (Farooqi and O'Rahilly, 2005, Farooqi and O'Rahilly, 2004). However, in the majority of genetic-related obesity this is due to a number of very small mutations across a variety of different genes, which can then lead to an increased predisposition to obesity development, this is known as a polygenetic mutation (Clement et al., 2002b). A detailed description of genetic mutations is beyond the scope of this thesis, however, some mutations under investigation are: *Ob gene* related to leptin production (a hormone which is involved in the control of appetite, hunger and metabolism) and also the *melanocortin- 4 receptor (MC4R)* which exerts a control on food intake and metabolic rate (Vaisse et al., 2000, Farooqi and O'Rahilly, 2004). More recently the *FTO* (fat mass and obesity associated) gene has been discovered and many studies have consistently found it to contribute to obesity risk (Dina et al., 2007, Fawcett and Barroso, 2010, Frayling et al., 2007).

1.3.7 Effect of psychological factors on overweight and obesity risk

Various psychological factors have been found to be associated with a child's weight status, however, the causal relationship of these is often unclear. There are few systematic reviews in this field and further research is required to reach a consensus on those factors which are of greatest impact. A full discussion is beyond the scope of this thesis, however, one recent review identified the major psychological risk factors as internalizing and externalizing disorders, attention-deficit hyperactivity disorder and sleep problems (Pulgaron, 2013). Psychological consequences of obesity will be addressed in Section 1.4.2.

1.3.8 Effect of race/ethnicity on overweight and obesity risk

Traditionally race refers to populations with shared biological characteristics while ethnicity refers to cultural characteristics. In reality there is not always an accurate distinction between the two and because of the constantly evolving nature of populations it is more precise to think of them both as referring to social characteristics. For the purposes of this study this concept will be referred to as ethnicity.

Ethnic disparities are commonly found when investigating individuals' risk of overweight and obesity, the explanation for this effect on body weight and health status may be as a result of several factors; genetic, cultural or socio-economic (Caprio et al., 2008, Taveras et al., 2010, Crawford et al., 2001), each of which will now be briefly discussed.

Genetics

The effect of ethnicity on genetics may contribute to several conditions which predispose an individual to overweight/obesity; among these are fat distribution, stress and insulin sensitivity (Caprio et al., 2008).

Research has shown patterns of fat distribution to be significantly different between ethnicities. A US study carried out in adolescents found African Americans to have less visceral and hepatic fat than Hispanic and White individuals (Bacha et al., 2003). This difference in fat distribution has also been found to vary not only by ethnicity but also by sex. However, the majority of studies have involved adults from developed countries with little data available from developing countries. Further to this the results of studies which have involved children have been inconsistent (Bacha et al., 2003). These differences emphasise the importance of body composition measures rather than pure weight based measures such as BMI, as individuals with similar BMIs appear to have varying levels of risk depending on their ethnicity.

Stress results in increased production of cortisol, a hormone which has been linked to increased risk of obesity (Bjorntorp and Rosmond, 2000). This link between stress and obesity appears to be affected by ethnicity. It is unclear whether specific ethnicities are inherently more vulnerable to stressful situations and therefore have a heightened biological response or whether they have developed different coping mechanisms. There is a call for more research on this subject.

Ethnic variations in insulin sensitivity have been noted and, in a consensus statement, Caprio highlights that African American and Hispanic children have a lower insulin sensitivity than white children (Caprio et al., 2008). Low sensitivity to insulin leads to increased insulin production, this in turn leads to low blood glucose which results in further hunger and therefore food intake which requires further insulin production; this vicious cycle results in hyperinsulinaemia and weight gain.

Culture

Cultural differences can relate to an array of factors which may include social norms, traditions and expectations of different members in society. The culture of populations is a constantly changing concept with developing regions increasingly being influenced by the Western world. The stage of Westernization plays an important role in the knowledge and beliefs of individuals and exposure to more attractive, modern practices seen in other cultures can lead to abandoning of traditional methods. These shifts in traditions or beliefs can have a significant effect on the importance placed on participation in physical activity, availability of health-related education and also the perception of ideal weight status; for example some populations may view obesity as an illness while others consider it to be an attractive and desirable feature (Caprio et al., 2008).

In many countries there is an association between large body size and desirable qualities such as power, beauty and affluence. In African American adults there is less social pressure to be thin and reduced social negativity towards obesity, there is often even a desire to gain and maintain weight (Prentice, 2006). A recent study of adolescents and adults in the Gambia showed high levels of body satisfaction and acceptance of overweight, especially amongst the older age groups (Siervo et al., 2006). Work carried out in small focus groups at the Africa Centre in 2009 also found similar results (Stefanie

Hyde, personal communication) and highlighted the fact that the association of thinness with HIV is thought to accentuate positive attitudes towards overweight, with the perception that being underweight or of a 'healthy' weight is a sign of HIV and therefore undesirable with the potential to lead to stigmatisation.

A recent review of overweight and obesity in South African children and adolescents found that overweight increased with age in black girls but decreased with age in white girls (Rossouw, 2012, Armstrong et al., 2006) and it was suggested that this was a result of differences in cultural perception of overweight.

Socio-economics

It is not always clear whether socio-economics are independent of ethnicity or not, however, socio-economics are often related to ethnicity in that certain ethnic minorities are often stereotypically more likely to be in a certain socio-economic class within society. See previous section 1.3.4 for discussion of the effects of socio-economics on weight.

1.3.9 Effect of gender on overweight and obesity risk

Males and females have a different biological makeup, including different levels of fat and muscle mass. Females require a larger percentage of body fat than males for the purposes of childbearing as well as other complex hormonal functions whereas males typically have a higher percentage of muscle than females resulting in the well known disparity in strength between the sexes. There is also a difference in the distribution of fat around the body with females having more overall peripheral fat and higher levels of fat in their legs while males have more in the trunk area (Nindl et al., 2002, Taylor et al., 2010).

Studies reporting on sex differences in overweight and obesity do not concur and suggest that level of development within the country may also be an important factor (Kanter and Caballero, 2012). Studies carried out in South African adults (van der Merwe and Pepper, 2006), children and adolescents (Kimani-Murage et al., 2010) found higher levels of overweight and obesity in females while those carried out in adolescents from more developed countries such as Greece and USA have found a higher prevalence in males (Tzotzas et al., 2008, Isasi et al., 2011).

A South African study of gender disparities in adults living in a township outside Cape Town found women were more likely to be overweight and suggested this was affected mainly by women's perceptions of an ideal body size, socio-economic status and early programming. However, neither early programming nor socio-economic status appeared to increase risk of overweight in men (Case, 2007). Another study, also carried out in adults from an urban township, found being female was associated with a higher BMI and larger waist circumference (Malhotra et al., 2008).

Large gender disparities in overweight/obesity prevalence are more noticeable in some ethnicities than in others. A study carried out in the USA by Wang et al reported a larger gender gap between both Non-Hispanic blacks and Mexican American children and adolescents than between those of Non-Hispanic white ethnicity. Girls had the higher prevalence of overweight/obesity in Non-Hispanic blacks but among Mexican Americans this was higher in boys (Wang and Beydoun, 2007).

Further research is required to reach a consensus regarding the effect of gender on obesity risk.

1.4 Consequences of overweight and obesity

The WHO estimates that at least 2.6 million people die each year as a consequence of being overweight or obese, with the majority of these deaths due to diet-related non-communicable diseases such as cardiovascular disease, stroke, heart attack and type 2 diabetes (WHO, 2011). Recent figures show that 66% of deaths from non-communicable diseases occur in the world's low income countries and, worryingly, these numbers are expected to increase further (Prentice, 2006). Given that non-communicable diseases are believed to be largely preventable through healthy lifestyles and a subsequent decrease in overweight and obesity, it is essential that the issue is given high priority and addressed appropriately. The importance of addressing this pandemic of overweight and obesity is therefore essentially due to the harmful health effects associated with an excess of weight and body fat.

Worryingly, there is a considerable body of evidence showing that overweight and obese children and adolescents are at increased risk of being overweight as adults and that this persistence is greater with increasing levels of overweight (Singh et al., 2008, Iughetti et al., 2008, Andersen et al., 2012). The high quality studies in the systematic review carried out by Singh et al showed that overweight children were at least twice as likely to become overweight adults compared to their normal weight counterparts, with some studies demonstrated a relative risk as high as 10; results of studies in obese children showed an even higher risk. The likelihood of persistence of weight status appeared to increase with age and therefore for individuals who were still overweight or obese when they enter adolescence the percentage who became overweight or obese adults ranged from 22 - 58% and 24 - 90% for overweight and obese respectively. All studies included in this review were conducted in high income countries and therefore these results may not be generalisable to populations in developing countries. Only one study was found which had been conducted in a developing country; this Brazilian study found persistence of overweight and obesity from adolescence to adulthood to be 65% in males and 47% in females. Given the lack of data there is an urgent need for further studies to be carried out in countries of the developing world.

Another important factor is that children with obese parents are at higher risk of becoming obese themselves (Brophy et al., 2009, Parsons et al., 1999) and therefore this can result in an inter-generational persistence of obesity (see Figure 1-3). However, a recent Cochrane review by Waters et al is quite positive about the prospects for behaviour change but concludes that the main difficulty is identifying the most effective intervention strategy to bring about that change (Waters et al., 2011). Again this review includes no evidence from studies conducted in Africa and very little from other developing countries with the majority of studies included being from the US and Europe (Waters et al., 2011). Interventions will be discussed further in section 1.5 and again in Chapter 9: Final Discussion.

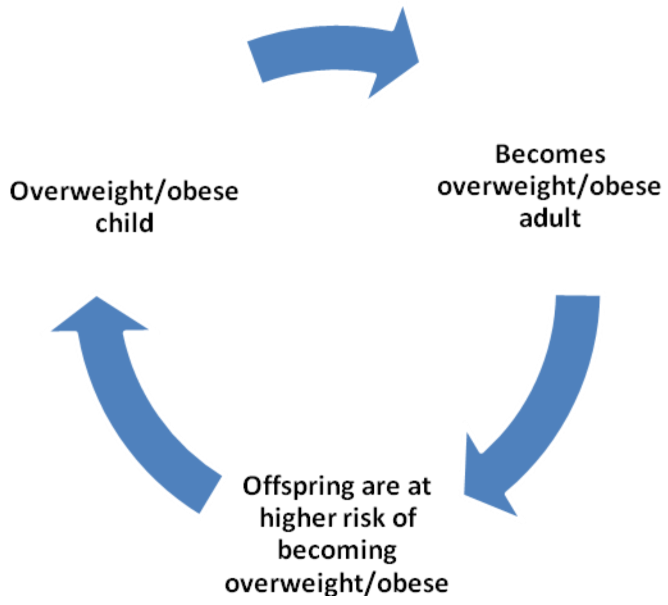

Figure 1-3 Cycle of overweight / obesity persistence

As mentioned above overweight and obesity bring with them a host of detrimental consequences, mainly health-related and can be both physical or psychological (Pulgaron, 2013). An additional consequence of obesity is the considerable economic strain it inflicts on the individual themselves and on the society within which they live. The following sections will describe these physical, psychological and socio-economic effects in more detail.

1.4.1 Physical consequences of overweight and obesity – both short (in childhood) and long (in adulthood) term

The physical effects of obesity can range from minor ailments which only marginally affect quality of life up to and including the development of more serious problems and diseases which can, in the longer term, result in increased morbidity and mortality.

Cardiovascular

Systematic literature reviews examining the health consequences of obesity in childhood have found consistent evidence to show that this state of overnutrition can lead to an increase in the existence of cardiovascular disease risk factors such as hypertension, dyslipidaemia, abnormal left ventricular mass and function, abnormal endothelial function, hyperinsulinaemia and insulin resistance (Reilly et al., 2003b). One of the 31 high quality studies cited in this review by Reilly et al found that 58% of obese 5-10 year olds (defined as BMI>95th percentile) already showed evidence of at least one cardiovascular risk factor and 25% had two or more. All studies included in this review were conducted in developed countries with no findings presented from developing settings (Reilly et al., 2003b).

A recent review examined the longer term impact of childhood obesity found that all 11 studies which assessed cardiometabolic morbidity (namely diabetes, hypertension, ischaemic heart disease and stroke) reported childhood overweight and obesity significantly increasing the risk of displaying these conditions in adulthood (Reilly and Kelly, 2011). All studies included in this review were conducted in developed countries, again highlighting the lack of data available from developing countries and the urgent need for studies to be conducted in this area to allow international generalisability of results.

Metabolic Syndrome (also known as Syndrome X or insulin resistance syndrome) is the collective name given to the condition in which an individual displays physiological evidence of a combination of cardiovascular risk factors. The exact definition used to describe the Metabolic Syndrome is still an ongoing debate with various organisations using different criteria (Grundy et al., 2004, Kassi et al., 2011). Figure 1.4 shows different criteria used for diagnosis in adults although different organisations select varying combinations of these and by definition an individual does not necessarily need to display all factors to be diagnosed with Metabolic Syndrome. Most organisations use a grouping of three or more to confirm diagnosis (Kassi et al., 2011). Organisations include World Health Organization (WHO), the European Group for the study of Insulin Resistance (EGIR), the National Cholesterol Education Program Adult Treatment Panel III (NCEP:ATPIII), the American Association of Clinical Endocrinology (AACE), the International Diabetes Federation (IDF), and the American Heart Association/National Heart, Lung, and Blood Institute (AHA/NHLBI).

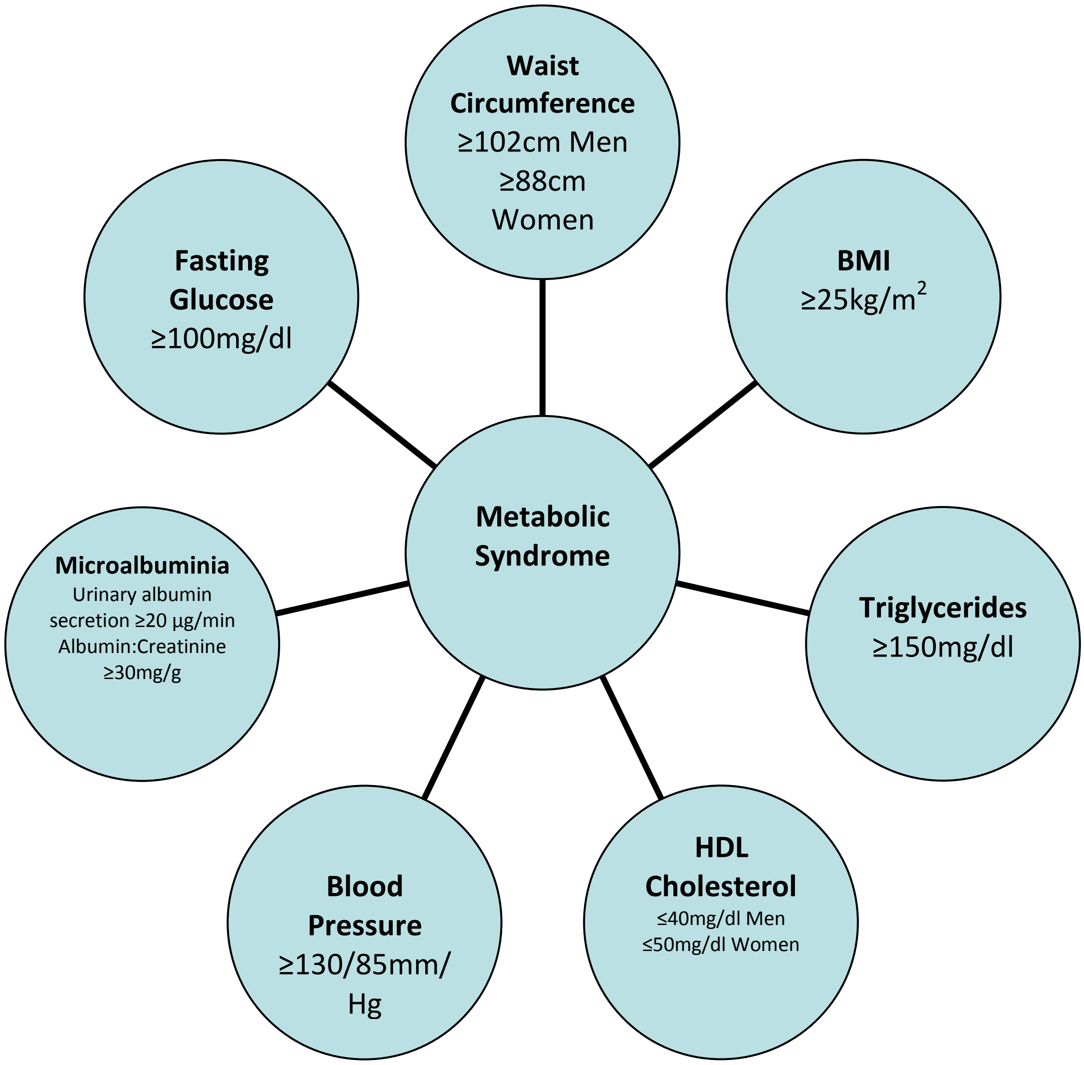

Figure 1-4 Criteria used for diagnosis of Metabolic Syndrome in adults

Recent increases in childhood overweight and obesity and subsequent diagnosis with Type 2 diabetes (previously perceived as a condition only affecting older adults) has highlighted the importance of diagnosing Metabolic Syndrome amongst children and adolescents in order to identify individuals at high risk for disease progression. The first article approaching the concept of Metabolic Syndrome in children was published in 1999 (Chen et al., 1999). Since then further studies have been carried out but unfortunately each has used their own definition of the syndrome therefore hampering the ability to make comparisons between studies. In 2007 the International Diabetes Federation published age-specific cut offs to be used for defining Metabolic Syndrome in children and adolescents (Zimmet et al., 2007) (See Table 1.5).

Despite these advances in definitions for the condition, there is ongoing debate surrounding the use of Metabolic Syndrome as a marker for cardiovascular disease risk and belief that each risk factor should instead be treated independently as opposed to clustered together (Kahn et al., 2005). Given this debate, use of Metabolic Syndrome as a diagnostic tool in clinical practice is now going out of fashion.

Table 1-5 Definition of paediatric Metabolic Syndrome, International Diabetes Federation (Zimmet et al., 2007)

Age Group (years)	Obesity (Waist Circumference)	Triglycerides	HDL Cholesterol	Blood Pressure	Fasting Plasma Glucose
<6	No definition				
6-10	≥90th Centile[a]	-	-	-	-
10 - <16	≥90th Centile	≥150mg/dl	<40mg/dl	≥130/85mmHg	≥100mg/dl or Type2Diabetes
16+	Adult criteria				

[a] This cannot be used to diagnose Metabolic Syndrome but further tests should be carried out if the individual has family history of Metabolic Syndrome, type 2 diabetes, dyslipidemia, cardiovascular disease, hypertension and/or obesity.

Insulin resistance/Type 2 diabetes

Insulin is a hormone produced within the beta cells of the pancreas, released in response to an increase in blood glucose and aids in the transport of this glucose into cells of the body for storage. This action reduces the potentially harmful high glucose concentration of the blood back to a safe level.

Where an individual presents with excess body fat this often results in a reduced sensitivity to the effects of insulin. This resistance to insulin leads to a situation where the blood glucose remains high and therefore the body produces more insulin in order to try and correct the problem, resulting in a vicious cycle of both high blood glucose (hyperglycaemia) and excess insulin (hyperinsulinaemia), both factors lead to further complications such as dyslipidemia, hypertension, non-alcoholic fatty liver disease and increases in weight status (Muntoni and Draznin, 2008, Filik, 2011).

Type 2 diabetes is essentially diagnosed when insulin resistance has reached such a level that it is now considered to be a chronic condition. This was previously considered a disease which only affected older adults however increasingly it is being found amongst children and adolescents with individuals as young as 6 years old having been diagnosed (Copeland, 2005).

Estimates show that the number of individuals with diabetes worldwide is expected to increase from 171 million in 2000 to 366 million in 2030 (Wild et al., 2004). Although Type 2 diabetes accounted for only 3% of all new onset paediatric diabetes cases 15 years ago (with the remainder being diagnosed with Type 1 diabetes), recent studies in the US have found as many as 45% of new onset paediatric cases are now diagnosed as Type 2 (Copeland, 2005, D'Adamo and Caprio, 2011). Worryingly studies carried out in Taiwan and Japan have found an even higher prevalence of new cases diagnosed as Type 2; 54.2% and 80% respectively (Pinhas-Hamiel and Zeitler, 2005). A crude estimate made in 2001 of the prevalence of Type 2 diabetes in children and adolescents in England was 0.038 per 1000, however, there is evidence that approximately 40% of these cases are found in individuals of South Asian origin as opposed to those of white British origin (Pinhas-Hamiel and Zeitler, 2005). This review by Pinhas-Hamiel presents data from every continent with the exception of Africa (Pinhas-Hamiel and Zeitler, 2005), again highlighting the need for further studies to be conducted within this under-researched geographical area.

The following criteria are used for the diagnosis of both Type 1 and 2 diabetes:

- Random blood glucose - ≥11mmol/
- Fasting blood glucose - ≥7.0 mmol/l (no calorie intake in previous 8 hours)
- Oral glucose tolerance test (OGTT) at 2 hours ≥11mmol/ (following a glucose intake equivalent to 75g anhydrous glucose dissolved in water)

The difference between Types 1 and 2 is the presence or absence of auto-immune markers; glutamic acid decarboxylase, IA2A, and islet-cell antibodies are present in Type 1 diabetes, however, there are no specific auto-immune markers for Type 2 given that it is primarily a diet related condition.

Obesity appears to be the most important risk factor in the development of Type 2 diabetes and increases in diagnoses of Type 2 diabetes are, in many cases, mirroring the increase in obesity prevalence (Copeland, 2005). Family history and ethnicity are also consistent risk factors, with reviews reporting higher incidences of Type 2 diabetes in

Hispanics, African Americans, Native Americans and Asians when compared to white populations (D'Adamo and Caprio, 2011).

Respiratory complications associated with overweight and obesity

Respiratory-related sleeping disorders have been associated with increased weight status, especially in the case of severe obesity; these disorders include heavy snoring and obstructive sleep apnoea in children (Reilly et al., 2003b). A literature review by Speiser et al found obese children to be four to six times more likely to suffer from sleep apnoea than their normal weight peers (Speiser et al., 2005). As well as being dangerous because of the reduction or periodic cessation of oxygen flow to the brain, sleep apnoea is also very detrimental to quality of life. In extreme cases individuals are required to wear an oxygen mask whilst sleeping, sleep can be extremely disrupted resulting in tiredness and related negative behaviours such as comfort eating which exacerbates the problem further. Children with sleep apnoea have also occasionally been found to present with neurocognitive deficits although the direction of causality for this is undetermined (Dietz, 1998).

Although previous reviews have discussed the fact that the relationship between obesity and asthma should not be assumed as causal and that the mechanism by which these two could be related is unclear (Speiser et al., 2005, Lobstein et al., 2004) a review by Reilly et al found obesity to significantly increase the risk of developing asthma in later life (Reilly and Kelly, 2011). A more recent systematic review also reported that although the exact mechanism is still unclear and warrants further research, prospective studies do find high body weight to precede asthma symptoms (Papoutsakis et al., 2013).

Orthopaedic problems associated with overweight and obesity

Although the body can withstand a certain amount of stress and strain exerted upon it, it has not been designed to withstand a constant pressure such as that endured in the presence of excessive body weight. This added strain can lead to several orthopaedic complications including Blounts disease (a condition in which excessive weight placed on the bones during growth leads to bowing of the leg), increased risk of sprains and fractures and abnormal foot structure such as flat feet (Reilly et al., 2003b, Reilly and Kelly, 2011, Dietz, 1998).

Other physical consequences of obesity also highlighted in recent reviews (Reilly and Kelly, 2011, Kopelman, 2007) include Polycystic Ovary Syndrome (PCOS), increased risk of developing certain cancers (although studies appear to be slightly inconsistent on this), liver and gall bladder disease. Reproductive function also appears to be affected in certain cases with increased risk of infertility in both males and females as well as a wide variety of maternal complications during pregnancy and birth (Reilly and Kelly, 2011, Kopelman, 2007, Linne, 2004).

It is widely accepted that as a result of the many complications detailed above overweight and obesity significantly increase risk of premature mortality (Reilly and Kelly, 2011, Kopelman, 2007, Linne, 2004).

1.4.2 Psychological consequences of overweight and obesity

Although overweight and obesity are often primarily considered a physiological medical issue, increasing research has found significant psychological effects. The mechanisms are complex as causality is not always clear; does obesity lead to psychological issues, do psychological issues increase risk of obesity or is there a possible bi-directional relationship.

A recent review examined the most commonly reported psychological factors associated with overweight and obesity identifying these as depression, anxiety, low self esteem, body dissatisfaction, dietary restraint, eating disorder symptoms and emotional problems (Russell-Mayhew et al., 2012). Individuals who are overweight are also at higher risk of teasing, bullying and stigmatisation as a result of their weight and this can often lead to the factors mentioned above and a subsequent decrease in quality of life. The majority of studies have found these issues to affect girls to a greater extent than boys (Russell-Mayhew et al., 2012, Puhl and Latner, 2007, Harriger and Thompson, 2012, Kalarchian and Marcus, 2012).

The review carried out by Russell-Mayhew calls for more attention to be placed on the psychological effects of obesity in order to facilitate a more comprehensive understanding and more conclusive evidence of the causes and effects of the condition. Again it appears that the majority of studies included were from developed countries therefore no conclusion can be made about whether these results would be similar in sub-saharan Africa or indeed any developing country (Russell-Mayhew et al., 2012).

The most recent literature review found indicated that common psychological co-morbidities of overweight and obesity include internalising and externalising disorders, attention-deficit hyperactivity disorder (ADHD), and sleep problems (Pulgaron, 2013). Although there were several studies included from developing countries such as Taiwan, Iran, Brazil and Egypt none of the studies included were from sub-saharan Africa (Pulgaron, 2013).

Meta-analysis investigating the association between BMI and health related quality of life in children and adolescents found obese children and adolescents to have a significantly reduced overall physical and psychosocial health-related quality of life (Ul-Haq et al., 2013).

1.4.3 Socio-economic consequences of overweight and obesity

The cause and effect relationship between socio-economics and obesity is bi-directional; a specific socio-economic status may predispose an individual to an increased risk of obesity but on the other hand being overweight could lead to detrimental socio-economic effects.

In western societies presenting with overweight and obesity is known to have an effect on an individual's socio-economic situation by negatively impacting educational attainment, later employment opportunities and therefore income prospects may also be reduced (Viner and Cole, 2005, Reilly et al., 2003b).

1.4.4 Effects of overweight and obesity on society and healthcare costs

In 2003, US medical expenditure solely attributable to obesity was estimated at $75 billion (approximately three quarters of the total education budget $90 billion)(US Budget, 2003). A more recent study in the US reported the cost of hospitalisation of obese children to have tripled in recent years (Silverstein and Styne, 2010) and the cost in adults to be a staggering $113 billion a year in medical expenses and lost wages amounting to 5 - 10% of total US healthcare spending (Silverstein and Styne, 2010).

It is estimated that China alone will lose $556 billion to heart disease, stroke and diabetes in the ten year period between 2005 - 2015 (Horton, 2005). An estimation of the projected economic burden of obesity in the UK and USA until 2030 found that the additional expenditure associated with treating non-communicable diseases related to obesity such as heart disease, diabetes, stroke and cancer would increase by £1.9 - 2 billion per year in the UK and by $48 - 66 billion per year in the USA by 2030 (Wang et al., 2011). These shocking statistics highlight the need for urgent action to be taken to address the obesity epidemic not only for the health of individuals but also for the future health of the international economy.

As obesity is often a bigger problem for ethnic minorities this may also affect the social structure of the country (Kimbro and Denney, 2012). The national workforce is also affected by obesity, for example national security may be at stake; the most common reason not to be accepted into the military is lack of fitness. In the US significant numbers of men and women of prime recruitment age exceed the weight limits of various armed services therefore significantly reducing the workforce available for recruitment. This issue was highlighted by the Surgeon General at a conference in 2003 as a major concern (NPC, 2012).

1.5 Summary of gaps in the current literature on overweight and obesity in children and adolescents

Prevalence

To address an epidemic it is crucial to monitor prevalence and trends (Lorenzo 2009). Reviews have highlighted the distinct lack of obesity prevalence data from developing countries especially with respect to prevalence in children (Rokholm et al., 2010); one recent review had too little data even to estimate statistics for sub-saharan Africa (Wang and Lobstein, 2006). While there is a suggestion of a leveling off of the obesity epidemic within children in developed countries it is not clear whether this is also the case in developing countries (Rokholm et al., 2010). It is important that prevalence is determined to assess the extent of the problem within developing countries and to inform the development of effective interventions. Data from South Africa are slightly better than from several other developing countries, however, significant gaps still remain especially from children and adolescents in rural areas.

Risk *Factors*

Previous studies have highlighted a lack of evidence linking environment, physical activity and obesity (Sallis and Glanz, 2006). The majority of studies assessing physical activity and sedentary behaviours have relied on self-reported methods which can lead to inaccuracies and bias. There is, therefore, a need for more studies using objective measurements based on the use of accelerometers and global positioning systems. (Wareham et al., 2005, Warren et al., 2010, Hallal et al., 2012, Ekelund et al., 2011). A recent Lancet series on physical activity highlighted the need for further studies in order to increase understanding of the reasons for physical inactivity and identify the correlates of physical activity both at the individual level and at higher levels. Multi level influences can be assessed using ecological models exploring the effects of economic conditions, urbanization and societal norms (Bauman et al., 2012). Identification of the most effective methods for promoting physical activity and reducing physical inactivity are essential to informing the development of future obesity interventions (Heath et al., 2012, Kohl et al., 2012).

Humans adapt readily to environments that promote sedentary behaviour and poor-quality food choices, and cultures exist where being active or eating ‘healthy’ foods are not high priorities and where there may be resistance to change. Further studies are required to assess the contribution sedentary behavior, diet and culture play in the obesity epidemic (Caprio et al., 2008).

Energy intake appears to have decreased in recent years despite a concurrent rise in obesity. However, although this is the case the composition of the diet has changed considerably; the presence and consumption of processed, refined fast food and drinks has escalated and the effect of these must be investigated further (Popkin, 2001, Popkin et al., 2012).

Relevant systematic literature reviews of early life determinants have highlighted infant feeding, extremes of birthweight, maternal smoking, maternal overweight and sleep duration as possible risk factors for later obesity (Monasta et al., 2010, Weng et al., 2012, Yang and Huffman, 2013).

Due to the complex nature of obesity, it is essential that multilevel analyses are conducted to allow adjustment for other confounding variables and to assess the potential risk attributed to each different factor. Few studies have used a multilevel approach and there is a significant lack of multilevel studies within sub-saharan Africa, with only one such study identified in South Africa (Kimani-Murage et al., 2011)

Interventions

There is as yet no official consensus on the best approach for interventions aimed at tackling the obesity epidemic. For effective interventions to be implemented to tackle this issue, it is essential to determine the most influential method to use. Given the complex nature of obesity and the differences in its aetiology between developed and developing countries it is likely that interventions should be largely population-specific. For population-specific interventions to be devised studies must be conducted within the relevant settings, specifically areas of the developing world where data are currently lacking. The majority of systematic literature reviews of interventions have included few if any interventions from low and middle income countries with only one systematic review found which focuses specifically on interventions in low- and middle-income countries yet this review found relatively little evidence from low- and middle-income countries (Verstraeten et al., 2012).

Changes to the micro environment alone are unlikely to solve the problems of increasing obesity and declining physical activity levels. A better approach is likely to involve complementary strategies and use of ecological models addressing individual, social and environmental factors. It is essential to determine which areas of an individual’s environment have the most significant impact on their risk of overweight/obesity, and then look at ways to combat these effects. There are distinct gaps in the data on both individual and higher level risk factors in South Africa.

Each country is unique and has different dynamics: with different levels of development, social structure, cultures, leaders, attitudes and stigmas and within each of these countries there exists a huge amount of variability in terms of ethnicity, population groups and age structure. Bearing this in mind it is imperative that studies take account of these differences at every stage of planning, data collection, analysis and especially during data comparison.

The environment will continue to be highly obesogenic unless governments and the food industry engage in major new initiatives to re-engineer the way we live. Studies must take place to investigate the main factors affecting this epidemic and interventions must take place in order to determine the most effective strategies for addressing the issue. The results from these studies will inform the best plan of action to be taken.

A paper in the recent Lancet series on obesity highlights new advances in terms of modelling techniques capable of quantifying the extent and aetiology of the problem and calls for adequate funding and a combined effort from all parties involved to work together for effective monitoring, prevention and control of this epidemic (Gortmaker et al., 2011).

1.6 Rationale for conducting the present study

There is a paucity of information on determinants of overweight and obesity in children in South Africa and, as highlighted throughout this Introduction, the relevant systematic reviews do not report on any studies from South Africa or indeed any sub-saharan African countries. Therefore this present study aimed to establish the scale of the obesity epidemic within a rural population of school children in South Africa, in an area where prevalence is currently unidentified amongst children, but where prevalence amongst adults is high (Barnighausen et al., 2008) and subsequently to make an effort to identify the leading risk factors within this specific population.

Based on the current literature available and existing gaps in the literature the specific aims of the present study will be laid out in Chapter 2 and a justification for the specific methods chosen will be discussed in Chapter 3.

2 Aims, hypotheses and power calculations

2.1 Aims

1. To determine the prevalence of overweight and obesity in children and adolescents (aged 7-15 years) within a rural South African population and the impact of community and household factors on weight status.

2. To examine the feasibility of measuring physical activity and diet within a rural South African population

3. To characterize physical activity and sedentary behaviour in this population as a precursor for future obesity prevention interventions.

4. To document differences in diet and physical activity between 7 and 15 year olds in this population.

2.2 Hypotheses and power calculations

Sample size and statistical considerations were discussed with epidemiologists at the Africa Centre (including Professor Marie-Louise Newell) and also a professional statistician at the Royal Hospital for Sick Children, Yorkhill and Strathclyde University, Dr David Young.

2.2.1 Cross-sectional study of prevalence

Aim 1

Primary hypothesis: The prevalence of overweight and obesity in this population increases with age, from 3-10% to 25-50% at 7 and 15 years respectively, as defined by Cole's international standards (Cole et al., 2000). **Secondary hypothesis:** The strength of the association of household and community variables with risk for overweight and obesity varies with age; for girls <11 years the dominant factor is distance to nearest water supply; for girls >11 years and boys of any age, distances to nearest road or school dominate.

Weight, height and BMI data will be linked to children's household and community data from the Africa Centre demographic surveillance system (DSS), allowing novel analyses of risk factors for childhood obesity and correlates of physical activity (e.g., distance from nearest water supply and road, household composition, socio-economic factors) in an explanatory analysis of the demographic correlates of obesity. DSS data are available at yearly intervals since 2000 and can thus be investigated for their importance at different ages of childhood.

Power calculation: In order to achieve 5% significance and a power of 80%, in determining the overall nutritional status (under or overnourished) of individuals within this population and in detecting differences both between the gender groups and across the three age groups, a sample size of 1,500, (500 subjects per age group) will be required.

2.2.2 Sub-sample study of physical activity and diet

Aim 2

Primary hypothesis: Data loss as well as reliability and stability of collected data will be of inferior quality to that in a matched western population.

Aims 3 and 4

Primary hypothesis: Even within this rural population, heterogeneity in physical activity will be considerable; 25% of children from relatively wealthy, peri-urban households have physical activity levels less than the recommendations for the developed world (60 minutes moderate - vigorous intensity physical activity (MVPA) per day) at all ages (no comparable South African studies exist and therefore this hypothesis was based on data from the Scottish Health Survey which found that 75% of similar age groups in Scotland achieve physical activity recommendations when assessed by questionnaire (see Chapter 9: Final Discussion/Conclusion)

Secondary hypothesis: I estimate dietary underreporting will increase with age as reported in previous studies (Rennie et al., 2005, Lioret et al., 2011, Lanctot et al., 2008).

Power calculation: In order to achieve 5% significance and a power of 90%, to detect differences in activity level between gender groups (mean difference in MVPA between sexes at any age of approximately 10 minutes per day; SD of 10), and 3 age groups (estimated decline in MVPA approximately 150 mins per day from age 7 to 15 years) (Trost et al., 2002), a sample size of 50 subjects per group will be required.

Using this sample size I also estimate that I will be able to detect with 90% power at 5% significance, differences in total energy intake and energy intake per kg between the gender groups and 3 age groups

3 Justification of methods to be used in the present study

The measurements used in this two-part study are divided into three categories: Anthropometry, Physical Activity and Diet. For each section the methods available for assessment are explained and then a justification is made in support of the method selected for the present study.

3.1 Anthropometric measures available

Anthropometry involves measurement of dimensions of the body and methods can be classed as direct or indirect (Wang et al., 2000):

i. Direct: Internal measures of specific body tissues which are then used either alongside other measures or via calculation to determine other components.
ii. Indirect: Exterior measurements of the body which are used as proxies to estimate internal body composition or health state, usually expressed in units of fat mass or percentage fat.

As discussed in Chapter 1: Introduction, the method of measuring body composition can be assessed by either direct or indirect proxy methods. Truly accurate body composition measurement is technically impossible to carry out in living persons (in vivo) as this would involve a full autopsy-like analysis of the whole body. Therefore, the majority of remaining methods involve some margin of error; they are somewhat predictive and rely on assumptions. Wells and Fewtrell describe the errors involved as both 'methodological error in the collection of raw data and error in the assumptions by which raw data are converted to final values' (Wells and Fewtrell, 2006). Methods primarily involve determination of fat and fat free mass and these are the constructs which are of considerable interest in the evaluation of nutritional status (Moreno et al., 2006).

3.1.1 Direct methods

Direct body composition measures may be 2 component; fat mass (FM) and fat free mass (FFM), or multi component (3 or 4), where the fat free mass element is further broken down into components such as water, protein and ash (mineral). Multi component methods are often worked out by determining 3 out of the 4 components and then using assumptions or calculations to determine the final component.

Reviews of literature were used to explain the methods described here, these included Reilly et al, Wells et al and Gibson (Reilly, 1998, Wells and Fewtrell, 2006, Gibson, 2005).

Methods available which measure specific components of internal body composition are

i. *Dual energy x-ray absorptiometry (DEXA)* - This technique uses x-rays of two different energies and measures their absorption in order to determine bone mineral mass. This provides a relatively accurate measure of FFM, however, measures of FM may not be so accurate given that they are measured indirectly by subtracting from FFM; for this reason body size and sex can affect results as body composition varies between genders and for different body sizes.

ii. *Densitometry* – Body density is measured based on the assumption that FM and FFM have specific densities. This is traditionally carried out by hydrodensitometry (underwater weighing) whereby an individual is fully submerged in a water-filled tank and the displacement of water is measured using the Archimedes Principle of water displacement to determine body density (mass/volume). More recent advances have increased the practicality of this method so that it can now be performed by air displacement (plethysmograph) rather than water displacement. This technique is unsuitable for use in individuals who may have an abnormal composition of lean mass, including diseases which affect fluid retention or mineralisation.

iii. *Isotope dilution (hydrometry)* – Water containing an isotope of deuterium is ingested and total body water (TBW) is calculated by measuring the distribution of the isotope in bodily fluids, such as saliva, urine or blood, by spectrometry. FFM can then be determined based on the assumption that FFM=TBW / 0.73. This assumes FFM is 73% water in adults. In infants, children, and adolescents age- and sex-specific constants for the hydration of fat free mass are used (Wells and Fewtrell, 2006).

iv. *Magnetic resonance imaging (MRI)* - This technique works by analysing absorption and emission of signals by body tissues and produces an image which essentially depicts the volume of adipose tissue (Fat Mass).

v. *Bio-impedance* – A technique used to measure body fat by sending an electrical current through the body and measuring the opposition which the electrical current experiences (impedance). Given that FFM is assumed to have a constant proportion of water (e.g., 73% in adults), this figure can be used to calculate total body water (TBW) and in turn FFM. Alternatively, TBW or FFM can be related to height, impedance and other values in a regression equation and this equation is then used to predict FFM. The FFM is then deducted from the individuals total body weight to give a reading which should equate to the individual's FM.

vi. *Skinfold thickness (SFT)* - This technique can be used both as a direct or indirect measure. Skinfolds can be measured at various sites around the body (using different methods) and a calculation made. In the case of multiple skinfolds being measured at different sites an estimation of total body fat can be made using prediction equations, for example those of Slaughter et al (Slaughter et al., 1988).

Other possible methods available but which are not commonly used, and for which there are no reference data, are: total body potassium (K+) and total body electrical conductivity. A detailed description of these is beyond the scope of this thesis, for further details see the paper of Wells and Fewtrell (Wells and Fewtrell, 2006).

3.1.2 Indirect methods

Reviews of literature were used to explain the various methods described here; these included Reilly et al, Wells et al, Gibson and Lohman (Reilly, 1998, Wells and Fewtrell, 2006, Gibson, 2005, Lohman, 1988).

Other methods available which can act as proxy measures for determining internal body composition are:

i. *Skinfold thickness (SFT)* – As described above, skinfolds may also be used to determine body composition indirectly. If a single skinfold measurement is taken it can be used as a proxy, this is only a measure of regional fat and not total body fat, so depending on the required outcome of the study it may or may not be appropriate.

ii. *Waist circumference (WC)* – Measurement around the waist. Again this is predominantly a regional measure and so may or may not be appropriate for use. However, it is possible to make assessments of overweight and obesity based on waist circumference.

iii. *Mid-upper arm circumference (MUAC)* – Measurement around the mid-point of the upper left arm. Most often used for screening of acute undernutrition but may have potential for diagnosis of overnutrition (this possibility is to be investigated in the present study, see Chapter 6: MUAC)

iv. *Body mass index (BMI)* – Weight and height are measured and then a calculation made (weight/height^2) to give an output which can be used as a health index. This is recognised as a global index and has been shown to display an association with mortality risk. BMI cannot distinguish fat or lean mass and this can be problematic especially in malnutrition, for example, undernutrition may result in a decrease in lean tissue and therefore an increase in proportion of body fat but this may not be evident from the BMI score. However, a recent systematic review found that BMI has a high specificity and moderate sensitivity for high FM and has also been found to be predictive of co-morbidities (Reilly et al., 2010c).

3.1.3 Advantages and disadvantages of anthropometric methods

Table 3-1 Methods of anthropometric measurement: advantages and disadvantages

Method	Advantages	Disadvantages
Dual energy x-ray absorptiometry (DEXA)	Relatively good accuracy and can have high precision	Involves a degree of exposure to radiation Affected by body size and sex as measures fat indirectly
Densitometry	New advances have led to more practical air displacement (plethysmography)	Impractical by water displacement (hydrodensitometry) Affected by disease state
Isotope dilution	Can be used in any population	Expensive Results are not immediate
Magnetic resonance imaging (MRI)	Good regional accuracy	Expensive Not readily available
Bio-impedance (BIA)	Quick and simple to perform	Relies on assumptions
Skinfold thickness (SFT)	Quick to perform Relatively simple	Requires training Accuracy in obese children is poor
Waist circumference (WC)	Simple measure May be good predictor of abdominal fat distribution and therefore lipid profile/insulin resistance Can be used in assessment of overweight/obesity	Children and adolescents are more emotionally sensitive about waist measurement Need reference data
Mid-upper arm circumference (MUAC)	Easy to administer Validated for use in diagnosing severe and moderate undernutrition. Inexpensive	Reading may be affected by various other individual factors e.g., muscle mass
Body Mass Index (BMI)	Quick, inexpensive and easy to administer Good diagnostic tool	Affected by individual factors e.g., muscle mass

3.1.4 Present study - anthropometric methods used

Given that this study was field- and not laboratory-based, the techniques needed to be practical for use in a rural field setting.

The techniques chosen for the present study were: measurement of body fat (by bio-impedance), height, weight and mid-upper arm circumference (MUAC). These techniques have previously been recommended by organizations such as the Scottish Intercollegiate Network (SIGN) and the World Health Organization (WHO) (SIGN, 2010, WHO, 1986, WHO, 2000). Each of these measures and their contribution to the study is described below:

i. *Body fat by bio-impedance* – It was hoped that a direct measure of body composition could be used in the present study in order to increase accuracy of results. However, the majority of direct methods are laboratory-based and therefore costly and impractical for use in field settings, especially in rural areas with few resources. One direct measure which can be used in a field setting is bio-impedance and therefore this was the chosen method. The bio-impedance Tanita device has been well validated for use in children and adolescents (Haroun et al., 2009a). A new, battery-operated, Tanita model (SC240-MA) had recently been developed that would allow measurement of participants in this rural area where electricity is often unavailable or unpredictable. Unfortunately, given this restriction I was unable to use a model which gave raw impedance information (ohms) as all models available require electricity and therefore it was not possible to use the newly devised equations by Haroun which were developed to allow estimation of body fat in different ethnic groups and which are based on raw impedance (Haroun et al., 2009b, Haroun et al., 2009a). The model (SC240MA) used in the present study gave body fat and body water data as a percentage, with the manufacturer's software. Given that the new ethnic-specific Haroun equations could not be used, the body fat reference curves developed for use in children and adolescents by McCarthy et al were used instead (McCarthy et al., 2006), these curves are categorised by age and gender and are based on the use of Tanita devices. This was a novel method for use within this population - to the best of my knowledge bio-impedance data has never been used in this or in any rural South African children and adolescents.

ii. *Height* – This is a practical, easy-to-administer and inexpensive method which provides essential information and allows use of sex-specific Height-for-age references which have been published by the WHO for children aged 2 - 19 years (WHO, 2007). These references are internationally recognised and are widely used in both clinical and research settings therefore allowing easy comparison of data between studies.

iii. *Weight* – A practical, easy and inexpensive measurement to administer. This provides an external body measure, essential for use in studies of overweight and obesity allowing use of sex-specific weight-for-age references. The CDC weight-for-age reference was used as the current WHO weight-for-age reference is only available up to 10 years of age (WHO, 2007, CDC, 2008).

iv. *BMI* - Height and weight were used in combination to allow calculation of BMI. BMI is an internationally recognised index for which references have been developed for adults and children and it has been validated in different populations, including African populations (Hall, 2006, Norris et al., 2009, de Onis et al., 2007). Internationally recognised BMI-for-age references from the WHO were used and these references are available for children aged 2 - 19 years. In addition to the WHO reference, recent references developed by Cole et al and by the International Obesity Task Force (IOTF) were used. These references were developed based on diagnosing thinness and overweight/obesity respectively (Cole et al., 2007, Cole et al., 2000) by linking 'adult' BMI values at age 18 years to earlier ages. Use of two BMI references would allow comparison between references when used in this rural population.

v. *MUAC* – This technique is most commonly used as a marker for diagnosing undernutrition and is especially useful in resource-poor, rural settings as it only requires use of an inelastic tape measure and the measurement process is easily taught(Roy, 2000). UNICEF has developed a colour-coded tape measure based on WHO child growth standards (WHO, 2009b); red, orange, yellow and green sections of the tape indicate severe acute malnutrition (SAM), moderate acute malnutrition (MAM), at risk for acute malnutrition and well nourished respectively; this method makes the tapes extremely easy to use and enables swift evaluation of an individual's malnutrition status and appropriate referral by first level health workers (See Figure 3-1).

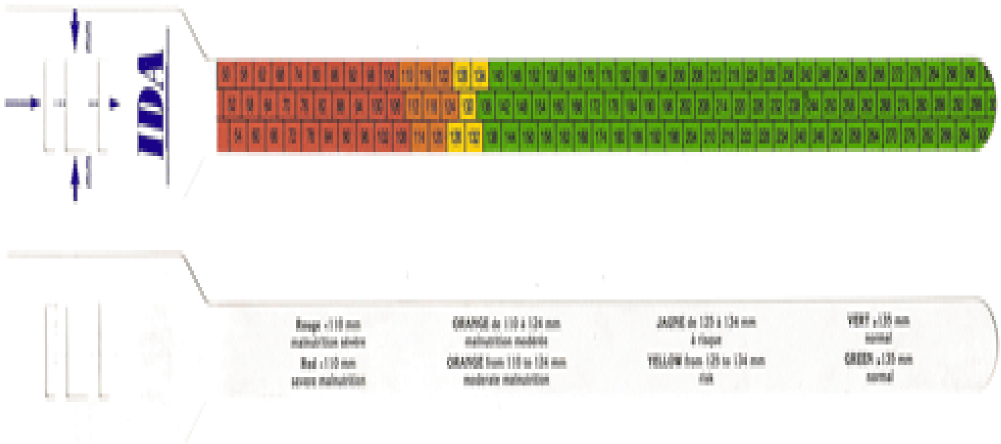

Figure 3-1 MUAC measurement tape

In this study, measurement would allow diagnosis and referral of any participants who were below the international guidelines for malnutrition and would also allow investigation into the possible use of MUAC as a diagnostic measure for overweight and obesity. There is a lack of MUAC data from large scale studies and therefore the data collected in this study would contribute to the existing evidence base.

3.2 Methods used in physical activity measurement

The information in this section has been taken from reviews of physical activity assessment including Warren et al, Corder et al and Melanson et al (Warren et al., 2010, Corder et al., 2008, Melanson and Freedson, 1996).

Physical activity has been defined as "any body movement produced by skeletal muscles that results in energy expenditure above resting level"(Caspersen et al., 1985).

In order to conduct studies which investigate the effects of physical activity on health or to allow implementation of physical activity based interventions there must first be an effective and accurate way to measure physical activity.

The gold standard for physical activity and energy expenditure assessment is direct calorimetry. This technique measures energy expenditure by means of precise measurement of heat production or loss from the body (Vanhees et al., 2005), however, it can only be carried out in laboratory conditions, is extremely expensive and, in the majority of cases is very impractical.

The remaining methods available can be categorized into three groups:

i. Criterion methods - these are relatively accurate techniques which are often used for validation of other techniques, given that direct calorimetry is often not feasible – these include indirect calorimetry, doubly labelled water (DLW) and direct observation. These methods are rarely practical in a field setting.

ii. Objective methods – these include accelerometers, pedometers and heart rate (HR) monitors as well as devices which combine both HR monitoring and accelerometry.

iii. Subjective methods – Questionnaires, diaries, activity logs and recalls.

Criterion methods

Indirect calorimetry – This is a technique which measures heat production indirectly by collecting data on O_2 consumption and/or CO_2 production and then converting this information into energy expenditure.

Doubly labelled water (DLW) – This is essentially a measure of CO_2 production which can then be used to calculate Energy Expenditure. An individual ingests a given quantity of water which contains two stable isotopes (^{2}H and ^{18}O). The ^{2}H isotope leaves the body as water ($^{2}H_2O$), however the ^{18}O isotope leaves as both water ($H_2{}^{18}O$) and carbon dioxide ($C^{18}O_2$), this therefore allows calculation of the difference in rate of elimination of the two isotopes.

Direct observation – For this procedure a trained observer watches the subject for a given period of time and notes down details of activity performed, that is then categorised or coded as required, e.g., into fields relating to frequency, intensity, time, type (FITT).

Objective methods

Accelerometer – This device measures acceleration of the body in terms of both amplitude and frequency. Accelerometers can measure acceleration in one, two or three planes (vertical, mediolateral and anterioposterior respectively). Data can be collected over several days and are pre-programmed prior to distribution to collect data in specific epoch lengths which can range from 5 - 60 seconds dependent on the population for example generally lower epochs are used for younger children as they may change activities quickly and longer epochs for older subjects. Accelerometers collect raw data in counts that can be converted into information on both total volume of physical activity or specific intensity of physical activity. Accelerometers are usually worn on a belt around the waist and placed on the hip but can also be worn on the thigh, ankle or wrist.

Pedometer – These devices collect information on the number of steps taken which can be used as a proxy measure of total volume of energy expenditure but are not designed to measure intensity. These devices are usually worn on a belt around the waist.

Heart rate monitor – Above a specific intensity of physical activity there is a linear relationship between heart rate and energy expenditure, this specific point is often referred to as the flex point. As this flex point and the linear relationship varies between individuals, calibration must be carried out prior to data collection in order to determine the individual's specific flex point.

As suggested above, devices also exist which combine both heart rate monitoring and accelerometry.

Subjective methods

Questionnaires – These are structured questionnaires usually developed specifically for the population under surveillance. They are designed to gain information on a particular aspect of physical activity and can be administered in a variety of ways: face to face, by telephone, post or on the internet.

Diaries and activity logs – The individual keeps a record of activities carried out and will often record details regarding intensity and duration where possible.

Recall – This is where the subject is prompted to remember what activities they took part in over a specific time period, e.g., the previous day.

There are several crucial questions to be asked before deciding on which method to use in a particular study.

Following a review of all physical activity assessment methodologies, Warren et al (Warren et al., 2010) suggest using a framework for choosing the most appropriate method.

This framework indicates that the first most important question would be:

What is the aspect of physical activity which the research question aims to address?

Aspects may include: Type of activity, energy expenditure, time spent in activities of varying intensities, duration and frequency or dose response relationship between physical activity and specific health outcomes. Each one of these aspects is best assessed by a different method.

Warren highlights that the following considerations must also be taken into account before a final decision is made:

i. Resources, cost and time available
ii. Competing areas of assessment in a research study and consequent participant burden
iii. Experience in assessment of physical activity
iv. Special considerations for population under study, e.g., literacy, cognitive ability
v. Capacity to undertake appropriate data handling and analysis

Table 3-2 Physical activity assessment methods and their advantages and disadvantages

Method of physical activity assessment	Advantages	Disadvantages
Gold Standard		
Direct calorimetry	Gold Standard – very accurate	Expensive Impractical Not suitable for free living measurements
Criterion		
Indirect calorimetry	Good accuracy Can be used to determine contribution of RMR, DIT and PAEE to Total EE*	Expensive Relatively impractical
Doubly labelled water (DLW)	Accuracy	Expensive Only gives measure of total energy expenditure, cannot determine physical activity intensity, type etc
Direct observation	Activities well categorised	Time consuming Tedious/labour-intensive
Objective		
Accelerometer	Subject cannot tamper with results as data collection pre-programmed Data collected in real time so allows for observation of patterns Provides information on volume and intensity	May not always capture upper body movement as placed on hip May underestimate certain activities such as load bearing where acceleration does not change but exertion does Challenge of determining non wear time vs. completely sedentary time

Method of physical activity assessment	**Advantages**	**Disadvantages**
Pedometer	Simple Inexpensive Well correlated to accelerometry/self report/direct observation Good as motivational tool	Each pedometer works differently so hard to compare between studies Subject could tamper with devices Only provides information on volume
Heart rate monitor	Good accuracy at high intensity once calibrated	Poor accuracy at low intensity Requires individual calibration prior to data collection
Combined heart rate/accelerometry	No difficulty of working out non-wear time Combination of the two techniques strengthens data	Relatively expensive
Subjective Questionnaires	 Inexpensive Easy to administer on large scale Provides structured results of different types of activity	 Difficult to accurately determine frequency, duration and intensity Must be culturally-specific and well validated May be affected by social desirability/personal opinion Not suitable for young children due to recall error
Diaries/activity logs	Inexpensive Easy to administer	Parent required as proxy for young children May be affected by social desirability

Method of physical activity assessment	**Advantages**	**Disadvantages**
Recall	Inexpensive Easy to administer	Reliant on memory and cognitive ability Not suitable for young children

***RMR= Resting Metabolic Rate, DIT= Diet Induced Thermogenesis, PAEE=Physical Activity Energy Expenditure, Total EE=Total Energy Expenditure**

"Adapted from (Warren et al., 2010, Corder et al., 2008, Melanson and Freedson, 1996)"

3.2.1 Aim of present study and method of physical activity assessment chosen

The present study aimed to assess the practicality of carrying out physical activity assessment in this population and the feasibility of its use in future studies, to collect preliminary and detailed information on the lifestyle of this population and to carry out an exploratory analysis to assess the relationship of free living physical activity to overweight and obesity. The physical activity assessment was carried out on a sub-sample equating to approximately 10% of the full sample from the cross-sectional study, these smaller numbers would allow collection of the most accurate data possible given the resources available.

The sub-sample study was a combined measure of physical activity and dietary assessment. The aim of the dietary assessment was to measure total energy intake as accurately as possible, therefore a similarly accurate measure of energy expenditure was necessary to allow comparison of results. Given that international guidelines for physical activity are based on moderate-vigorous physical activity (i.e. intensity), ideally the method chosen would allow us to investigate this aspect of physical activity to assess whether guidelines were being met within this population. It was intended to use a technique which did not rely on literacy given that this may be a limiting factor in the present population (data from the Africa Centre Database (ACDIS) suggests approximately 30-40% of mothers in the present sample either never went to school or only attended some of primary school). It was also important that the method was not affected by cognitive ability given that the age range of the population in question was varied. It was ideal that participant burden should be kept to a minimum in order to maximise compliance. Criterion methods for assessing physical activity are relatively impractical, mainly laboratory-based and the cost and equipment required were beyond the resources available in the present study (Vanhees et al., 2005). Subjective measures were also deemed to be inappropriate given their reliance on cognitive ability and literacy as well as their inability to accurately assess exact levels of energy expenditure. Therefore, in order to meet the needs of the present study an objective measure was required and it was also decided that use of an inexpensive subjective measure alongside the objective measure would be feasible and may help strengthen results. Based on the framework outlined above and taking all factors into account a decision was taken that accelerometry would be the method used for physical activity assessment in this study – pedometers would not give any information regarding intensity of activity performed and funds were available to use a more accurate measure. Heart rate monitoring was not feasible with relation to cost or time and it was also not suitable given that the present study aimed to assess total free living activity (sedentary, light and moderate/vigorous) and not just moderate-vigorous intensity physical activity which is the construct best assessed with heart rate monitoring (Warren et al., 2010).

3.2.2 Justification for choosing accelerometry

Accelerometry is a method of physical activity assessment which has been well validated against criterion methods in children and adolescents (direct observation, indirect calorimetry and doubly labelled water) (Prista et al., 2009, Reilly et al., 2003a) and a recent systematic review deemed it to be a reliable, practical and valid method of physical activity assessment (De Vries et al., 2009). Use of accelerometry would therefore provide relatively accurate data whilst also allowing information to be obtained on both volume and intensity. Assessment of the relationship between physical activity and overweight/obesity would also be possible.

This would be used alongside an activity log which would then be utilised during analysis to help with determination of non-wear time throughout the day. The main reason for the activity log was for subjects to document the time the monitor was put on and taken off each day, although they were also welcome to add in any more detailed information they wished, a technique that has been used in previous studies (Fisher et al., 2005).

The justification for using accelerometry is explained below using each of the decision making steps suggested by Warren et al (Warren et al., 2010).

Resources, cost and time available

Several devices and accompanying equipment such as accelerometry belts, cables etc were already available for use and funding was obtained to purchase the additional devices required (see Appendix 3 'study budget and resources').

Given that the fieldwork for this study was to take place over the course of a year this would be adequate time to administer the available accelerometry equipment across the full sub-sample in rotation.

Battery life of the accelerometers is lengthy (approx 20 days) and therefore would allow a substantial amount of information to be collected from each participant.

Competing areas of assessment in a research study and consequent participant burden

Accelerometers do not exert much burden on participants except for remembering to put them on and take them off, they are comfortable to wear and therefore do not disrupt participation in daily activities (Chen and Bassett, 2005). The accelerometers (Actigraph GT3X) chosen were tamperproof, are pre-programmed prior to distribution and therefore the participant has no way of accessing or amending information collected.

Activity logs are known to be related to some level of participant burden, however, it was to be emphasised to participants that the most important factor was wearing the accelerometer and completion of the activity log could be as simple as noting on and off times, as opposed to writing a full description of the day's activities.

Experience in assessment of physical activity

The Human Nutrition department at the University of Glasgow, where the author (EC) is based, is extremely experienced in accelerometry with many studies having been conducted and papers already published (Penpraze, 2006, Fisher et al., 2005, Reilly et al., 2004). An expert on accelerometry (Viki Penpraze, Glasgow University) was available to train the author in the process from programming and use of the devices to subsequent analysis of data, as well as offering further advice or guidance needed throughout the course of the study.

Special considerations for population under study, e.g., literacy, cognitive ability

As previously described, the population under investigation was of varying literacy levels and cognitive abilities; partly as it was based in a rural area of South Africa and specifically due to the fact it involved children and adolescents across a wide age range. As accelerometers are objective and do not require any participant input except for the individual to remember to wear it, this was deemed to be an appropriate technique for the given population.

Capacity to undertake appropriate data handling and analysis

Full training was given by an accelerometer expert prior to commencement of the study. The full software package Actilife 4.1 was available for use, allowing programming, initialisation of devices and downloading of completed data. In order to obtain practice in their use and analysis the accelerometers were worn for several days by the author and all data analysed.

Full specifications for the GT3X accelerometer used in this study are shown in Figure 3-2.

Tri axial, solid state accelerometer
Dynamic Range +/- 3G
Dimensions 3.8cm x 3.7cm x 1.8cm
Weight 27g
Battery Life 20 days fully charged
Resolution 12-bit A/D conversion
1.46mG(Raw data)

Figure 3-2 Specifications: Actigraph GT3X accelerometer

A full description of the use of this technique for the present study is given in the following chapter (Chapter 4: Methods).

3.3 Methods available for use in dietary assessment

The information in this section has been taken from reviews of dietary assessment including Burrows et al, Rankin et al and Bingham et al (Burrows et al., 2010, Rankin et al., 2010, Bingham et al., 1994).

As is the case for physical activity assessment, a number of methods are available for dietary assessment, each with different techniques for gathering data and advantages and disadvantages that make them appropriate for use in different types of studies. Dietary assessment has been in use for many years however methods are constantly being updated and redesigned to make them more efficient and accurate. There are 4 main methods for use, these are:

i. 24 hour recall
ii. Food frequency questionnaires (FFQ)
iii. Diet history
iv. Diet record

24 hour recall

First used by Wiehl et al in 1942 this technique involves an interviewer asking an individual about the foods which they consumed over the previous 24 hours. In the 1990s a variant on this technique was developed in which questions are asked in a variety of ways, ensuring that the individual is helped to remember and recall to the best of their ability in order to maximise accuracy. This process of asking different questions in order to improve the accuracy of the answer or gain extra information is known as ’multiple pass’. Information is noted regarding foods eaten, brand names, quantity, method of preparation and time of day. In the present thesis where 24 hour recall is mentioned this refers to the multiple pass 24 hour recall.

Food frequency questionnaire (FFQ)

Originally devised by Willett et al in 1986, this technique aims to obtain frequency information on a variety of different foods over a lengthy period of time such as 6 months to 1 year. It usually consists of a pre-printed list of a large number of foods; the subject is asked to complete the form indicating their frequency of consumption of specific items/food groups. The scale used for this varies on the length of time being studied and each questionnaire must be predesigned and validated specifically for the population being studied.

Diet history

First used by Burke et al in 1947 this is a retrospective technique prompting the subject to think over ‘usual’ eating habits, it can consist of a combination of other techniques: 24hour, FFQ and general questions on habitual intake/eating patterns.

Diet record

First developed in 1930s by Widdowson and McCance, this method is prospective and involves the subject recording all foods eaten over a specified time period. This may be implemented either by weighing each food (cooked/uncooked) or simply by estimating quantities of each food. Subjects are usually provided with a log book for recording data and weighing scales if they are weighing foods. This is usually done over a period of 7 days in order to give an idea of habitual intake however it can be done for longer or shorter periods.

Table 3-3 Dietary assessment methods and their advantages and disadvantages

Dietary assessment method	Advantages	Disadvantages
24 hour recall	Found to be well validated against DLW (Burrows et al., 2010) Multiple pass technique ensures thoroughness Low subject burden Single short interview enables recruitment of relatively large numbers	Requires trained interviewer therefore relatively expensive Relies on memory, estimation of portions and decision on how representative the past 24 hours was of normal dietary pattern
FFQ	Moderate burden Can administer in person, by post, email or phone Large numbers	Questions must be study/population specific Relies on memory Poor precision
Diet history	Describes usual consumption over a long period	Labour, time and skill intensive High subject burden
Diet record • Weighed	Provides accurate information Can categorise meal patterns	High subject burden, can affect compliance Can only collect for limited period
• Estimated	Errors well understood Easier than weighed, increased compliance Can use household measures	Increased errors due to estimation, relies on individuals opinion/knowledge Relatively high subject burden

3.3.1 Considerations when choosing a dietary assessment method

A recent review of dietary assessment methodologies by Magarey et al (Magarey et al., 2010) lays out several considerations when choosing a dietary assessment method (Table 3-4).

Variable of interest - is the aim of the research to investigate total energy intake, specific foods/food groups or eating behaviours?

Study design and depth of output required – will information be required at individual or group level? Are the results concerned with differences in total intake, macronutrients or even micronutrients?

Target group – this may relate to sex, age, race cognitive ability, literacy or specific health issues

Practicalities – this may include factors such as resources available, method of administration, time constraints and analysis procedures required

Existing tools available in this population – use of any validated tools already available would allow faster and easier preparation of the technique and would add to existing knowledge of the tool.

In the present study the primary variable of interest regarding diet was total energy intake, however, the study also aimed to assess the feasibility of using a dietary assessment technique within this rural South African population and to investigate factors such as data loss, time taken to collect data and probability of misreporting.

The dietary information would be required at group level to allow assessment of difference in energy intake between healthy and overweight and obese participants with the target group being rural South African school children aged 7 - 15 years old. The practicalities and scope of available resources, time and expertise were taken into consideration and availability of existing tools was researched, previous dietary data collected in this area was noted and South African dietary experts were contacted and asked for advice (N. Steyn, M. Lombard). Taking into consideration all of the above factors it was decided that 24 hour recall was the method to be used for dietary assessment in the present study.

Table 3-4 Dietary methodology checklist

Dietary Methodology Checklist
Determine the dietary outcome of interest based on the study hypotheses Nutrients Foods Behaviours Eating patterns • Do you want to measure the usual intake of an individual or a group? • Do you require absolute intake levels or to rank individuals according to high and low intake? • What sample size is required to obtain a reliable estimate and/or detect change?
Decide what type of study design you will use • Timeframe • Study population
Consider your study population • Subject burden • Potential for bias • Literacy skills • Influence of body weight
Consider practicalities of the research and impact of the methodology • Resources: personnel, expertise, budget, time • Data management • Investigator burden, time, bias • Over and/or underreporting
Is there an existing dietary assessment tool? • Appropriateness for the hypothesis • Appropriateness for the local context (e.g.,, food supply and local eating patterns) and study population • Has reliability and validity been determined? If not what steps should be taken to validate the tool?
Decide on appropriate tool • Total diet • Targeted

3.3.2 Justification for use of multiple pass 24 hour recall in present study

Variable of Interest - Energy intake was the primary variable of interest to allow comparison with energy expenditure data from accelerometry data, to assess feasibility of the method and to collect some preliminary data on dietary intake from this population.

Study design and depth of output – The study was a sub-sample of individuals from a larger cross-sectional study and information was to be collected at the group level.

Target group - The target group was rural South African school children and adolescents aged 7 - 15 years old. This population spans a wide age range and varying levels of literacy and cognitive ability. Both diet records and diet history were believed to possess too high a subject burden to be appropriate for use in this population, and, given the young age of some of the sample administration of these techniques would be impractical and would require a significant amount of parental participation; a factor which may unnecessarily lower compliance.

A recent systematic review concluded that multiple pass 24 hour recall is the most accurate method of measuring usual energy intake in children aged 4 - 11 years when compared to DLW (Burrows et al., 2010). A further review, specifically of dietary assessment in South African children and adolescents, concluded that FFQs and 24 hour recalls were both valid and reproducible methods to use with adolescents, with the 24 hour recall method displaying the least under and over estimation of energy intake measurement of all methods considered (Rankin et al., 2010).

The National Food Consumption Survey (NFCS) carried out in South Africa on a nationally representative sample of children aged 1-9 years used 24 hour recall and a FFQ for dietary assessment. This information was collected from the caregivers of the children, who acted as proxy reporters, given that the children involved in the study were still young (Labadarios et al., 2005). This survey would provide a useful source of comparison to the results from the present study, given that a similar method had been used and the children were of a similar age to those in the youngest age group in the present study.

The use of parents as proxies for reporting dietary intake is recommended for children aged less than 7 years (Livingstone and Robson, 2000): this is due to the fact that young children have limited cognitive ability and literacy levels and therefore often struggle with estimation of portion size, timings and knowledge of foods and food preparation. Some studies have used parents as proxies for children beyond the age of 7 years due to the belief that there is a transition period between the ages of 8-12 years when children gradually increase their accuracy of report (Burrows et al., 2010, Labadarios et al., 2005). Parents have generally been found to be reliable reporters of their children's food intake (Johnson et al., 1996), however, one concern is how accurately they report consumption of foods outside the home, given that they will not always be with the child at all times of the day (Baranowski 1991).

Practicalities - Resources were available to allow employment of a native Zulu speaking fieldworker with a background in nutrition to assist with the administration of the dietary assessment. The sub-sample fieldwork was conducted over a period of approximately six months and therefore there was adequate time available to complete interviews for all participants. The average time taken to complete each interview was approximately 30 - 45 minutes and therefore it was possible to carry out several interviews each day.

It is accepted that use of a single 24 hour recall has limited capability to accurately determine usual energy intake of individuals (Ma et al., 2009), however, the optimal number of 24 hour recalls required is a topic of ongoing debate (Arab et al., 2010), with studies suggesting repeat measures of anything up to 7 days (Basiotis et al., 1987, Nelson et al., 1989, Wassertheil-Smoller et al., 1993). A recent study analysed the results of 24 hour recalls performed over 7 days and concluded that three days provides optimal estimation of energy intake. However, it is stressed that factors such as age, ethnicity and mode of administration must be taken into account when a decision is made (Ma et al., 2009, Arab et al., 2010). It is generally accepted that conducting repeat interviews on non-consecutive days is beneficial and may prevent a day-to-day recall bias; if possible inclusion of a weekend day is also thought to be advantageous in order to include both mid-week and weekend eating habits (Burrows et al., 2010).

Based on available evidence and due to the fact it was practical for the purposes of the fieldwork, as well as being an acceptable burden for the participants, 2 days of dietary recall were carried out for each participant in the present study; these took place on non-consecutive days around 1 week apart, at the beginning and end of the accelerometry wearing period. Collection of 2 recalls would provide data which could be analysed at the group level. As described above, use of parents as a proxy for dietary report was necessary in the youngest age group (age 7 years) and therefore participants in this group were visited at home as opposed to at school.

Existing tools – FFQ was initially considered a possible method however no population-specific questionnaires were available and there was a lack of time and resources to be able to design and validate a new questionnaire. 24 hour recall is a technique which has been used previously in South African children and adolescents and recently a country-specific standard layout has been designed and validated by the MRC South Africa. Country-specific manuals and software are also available, see below for details.

3.3.3 Equipment and software available and used alongside the 24 hour recall method in the present study.

MRC Food Photo Manual (Appendix 21)

The Food Photo Manual has also been put together by the South African MRC and includes pictures of different food portion sizes i.e. different sized cups, bowls, plates, spoons holding varying quantities, e.g., ¼ full and ½ full.

The manual is divided into 14 different colour-coded food groups as follows

1. Dairy
2. Starch
3. Fat
4. Spreads
5. Eggs
6. Fruit
7. Soups, Legumes, Nuts
8. Fish, Seafood
9. Meat
10. Vegetables
11. Biscuits, Cakes, Pudding
12. Snacks, Sweets, Cold drinks
13. Sauces, Condiments
14. Alcoholic Drinks

Each group contains pictures of different items, brand names, and what their relative quantity would be using normal household measures, e.g, ½ shallow bowl of white rice would be 65g, 1 medium strawberry 12g, 1 slice thick bread (15mm) 50g.

A recent study used food drawings and found that black South African adolescents (aged 12 - 13 years) judged quantities more accurately than white South African adolescents (Steyn et al., 2006).

Foodfinder3 software

Foodfinder3 is a South Africa-specific software package developed by staff from the nutritional and biomedical departments (Nutritional Intervention Research Unit (NIRU) and Biomedical Informatics Research Division (BIRD)) of the South African Medical Research Council (MRC) to allow analysis of food intake. This program was used for the input of all dietary data. Entry is made for each individual and split into different meal times: breakfast, lunch, dinner and snacks. Food items can be entered in terms of household units or grams. This program then automatically calculates the nutritional information; which can be done by mealtime or for full days (See Appendix 22).

A full description of the administration and analysis of this technique is explained in the following chapter (Chapter 4: Methods).

4 Methods

Following a brief overview of the general study design and its two parts, this chapter is then organised into 7 sections:

1. **Study context/setting** – this section describes the geographical location of the site where this study took place and an overview of the Demographic Surveillance Area (DSA) of the Africa Centre for Health and Population Studies within which this study took place. Given that this was a school based study, a basic structure of the schooling system in South Africa is then described.

2. **Ethical permissions and clearance** - a diagram of the biomedical ethics process is presented as well as an explanation of other clearance requirements.

3. **Full description of cross-sectional study** – this includes details of study preparation, translation of forms and assessment measures. Thereafter, the study procedures are outlined, including the recruitment procedures, inclusion and exclusion criteria, study protocol and data entry procedures.

4. **Full description of sub-sample -** including sample selection procedures, methods used in collecting data and data entry.

5. **Staff** – roles and responsibilities of fieldworkers.

6. **Variables available from the Africa Centre Demographic Information System** – explanation of reasons for choosing variables available within the Africa Centre datasets and which ones were chosen.

7. **Analysis of data** - detailed description of statistical analyses used in both studies.

General overview of the full study (two parts)

Part 1 Cross-sectional study examining prevalence and correlates and risk factors of overweight and obesity in rural South African children and adolescents

A cross-sectional study (sample size n=1500) of children and adolescents aimed to investigate the prevalence of overweight and obesity at three different age groups; approximately 7, 11 and 15 years old (corresponding with school grades 1, 5 and 9) and quantify the impact of individual, household and community factors on overweight/obesity in this population. Height, weight, percentage body fat and mid-upper arm circumference (MUAC) was measured to determine prevalence. A lifestyle questionnaire was also administered to each child to explore risk factors associated with obesity including questions regarding water collection, method of travel to school, TV watching and sport participation. Data were linked to the child's household/community data (from Africa Centre Demographic Information System ACDIS), to allow analyses of risk factors for child and adolescent obesity and correlates of physical activity (e.g, distance from nearest road or school).

Part 2 Sub-sample to explore characteristics of physical activity and diet in rural South African children and adolescents

Dietary intake, physical activity and sedentary behaviour were measured in a randomly selected sub-sample of children and adolescents (sample size n=150; 50 participants at 7, 11 and 15 years).

Dietary intake was measured by interview administered 24 hour recall on two separate occasions with the aid of the Dietary Assessment and Education Kit (DAEK) (MRC, 2004) developed by the South African Medical Research Council, based on foods described as commonly eaten in the South Africa National Food Consumption Survey (Labadarios et al., 2005).

Physical activity and sedentary behaviour were objectively measured by 7 day accelerometry using 'Actigraph GT3X' accelerometers; a 7 day activity diary was also completed.

4.1 Study context and setting

4.1.1 South Africa

South Africa (officially the Republic of South Africa) is a large country in sub-saharan Africa with a population of 51.77 million (Census 2011) residing across its nine provinces. The majority of the population are of African (black) origin (79%), while the coloured and white populations each account for approximately 9%. The remainder of the population is Indian/Asian (2.5%) and those who classify themselves as 'other' (0.5%)(StatsSA, 2012).

South Africa has 11 officially recognised languages, these include: Afrikaans, English, isiNdebele, isiXhosa, isiZulu, Sesotho sa Leboa, Sesotho, Setswana, siSwati, Tshivenda, Xitsonga. The 2011 census found isiZulu is the most common language spoken at home, spoken by almost one quarter of the population (StatsSA, 2012).

Data for this cross-sectional study were collected within a rural area of the KwaZulu-Natal province in South Africa. Figure 4-1 displays the nine provinces of South Africa.

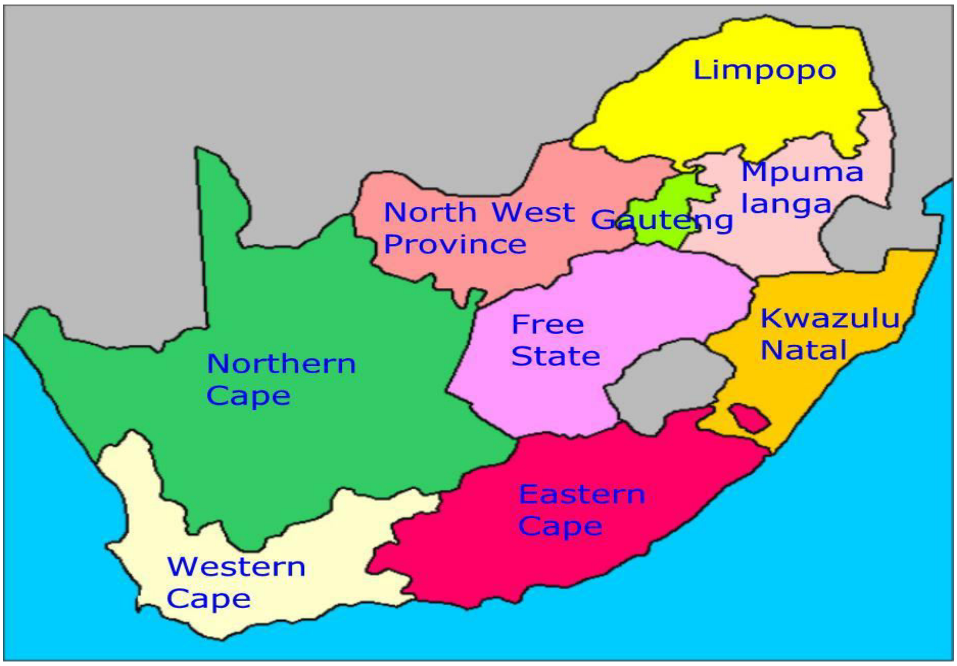

Figure 4-1 Provincial map of South Africa

Large scale surveillance studies of overweight and obesity prevalence in children and adolescents which have previously been conducted or are currently still in progress across South Africa include the National Food Consumption Survey (NFCS)(Labadarios et al., 2005), the Health of the Nation study (Armstrong et al., 2006), THUSA BANA study (Kruger et al., 2006) and the Birth to Twenty study (Bt20)(Richter et al., 2007). Those studies which are relevant to the present study will be introduced throughout the thesis at the appropriate time.

4.1.2 Africa Centre

The work was carried out at the Africa Centre for Health and Population Studies www.africacentre.com (from here on referred to as 'Africa Centre'). The Africa Centre was established in 1997 and is a Wellcome Trust - funded organisation conducting policy-relevant, health and population research within the Hlabisa Sub-district of KwaZulu-Natal. The Africa Centre operates a demographic surveillance system (DSS) and HIV surveillance system in the south-eastern tribal area of the district, Mpukunyoni. This area of approximately 430km², is the most populated and least mountainous area of the district and contains the only township - KwaMsane (Tanser et al., 2008). Figure 4-2 displays the location of the Hlabisa sub-district within the KwaZulu-Natal Province, South Africa and is followed by Figures 4-3 and 4-4 which give more detailed maps of the Africa Centre Demographic Surveillance Area (DSA), displaying primary and secondary schools respectively.

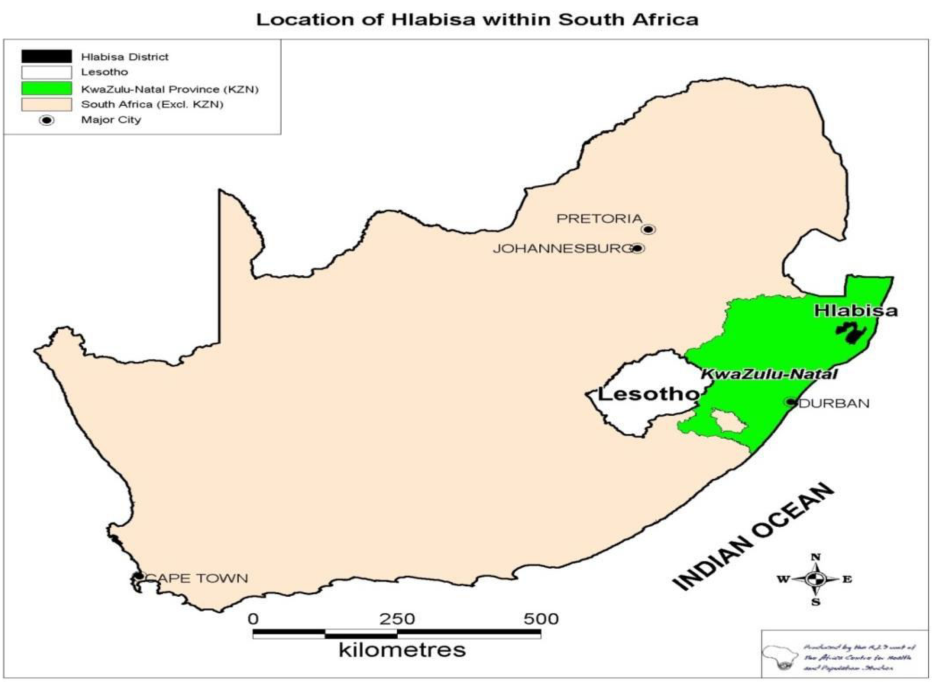

Figure 4-2 Map indicating location of the Hlabisa sub-district within South Africa

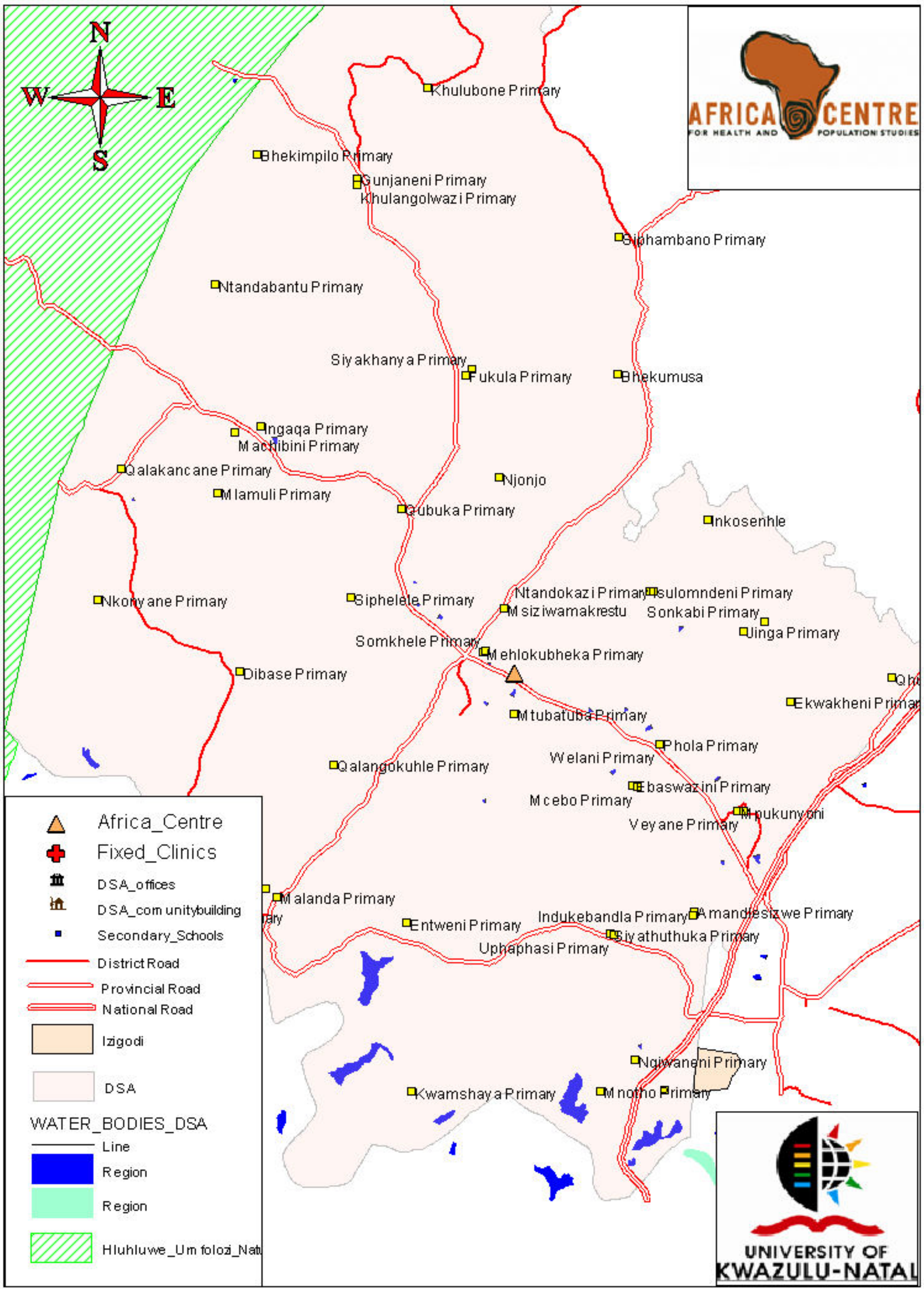

Figure 4-3 Map of 46 primary schools in Africa Centre Demographic Surveillance Area (DSA) (Scale 1 : 57,470)

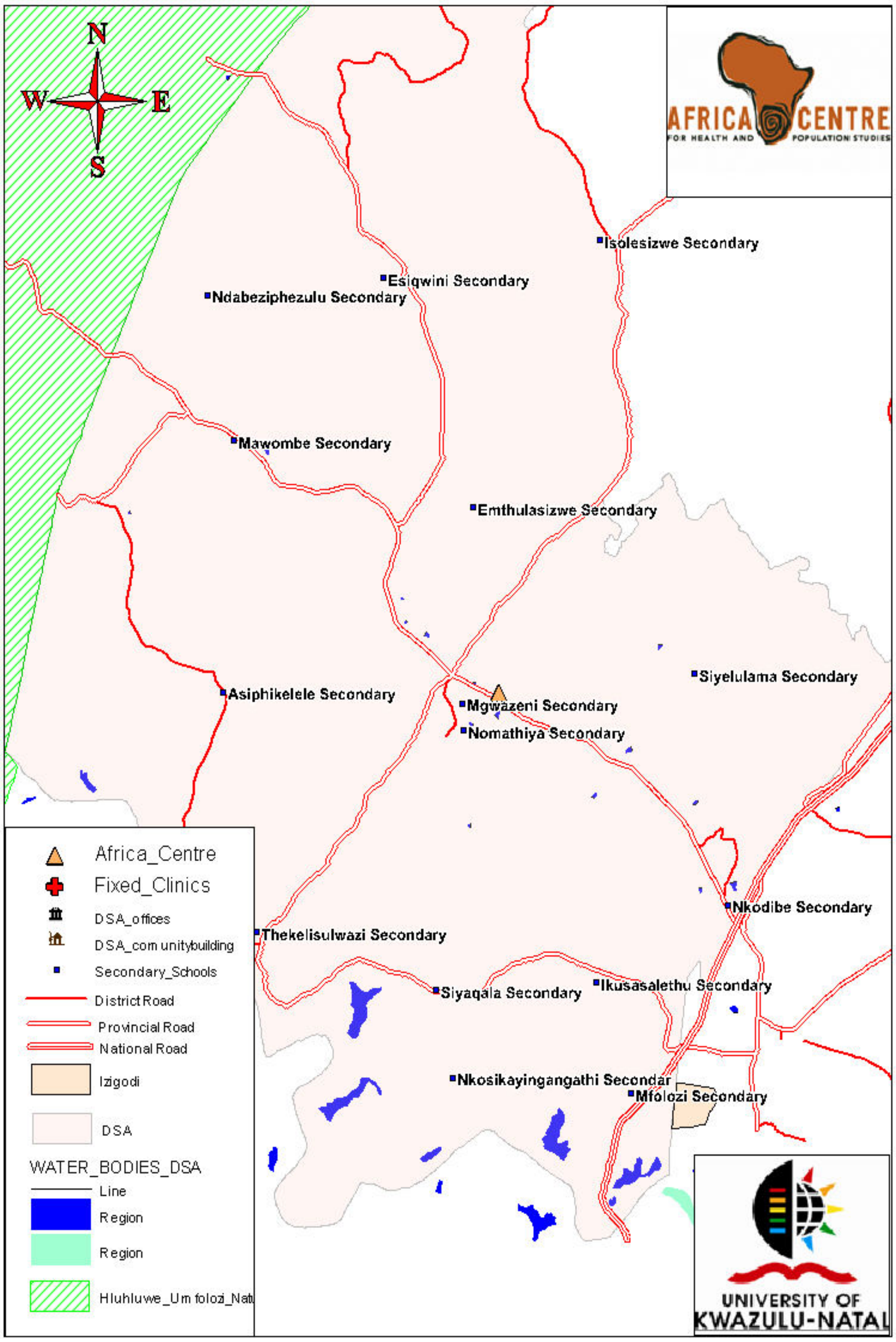

Figure 4-4 Map of 15 secondary schools in Africa Centre Demographic Surveillance Area (DSA) (Scale 1 : 57,470)

The resident Zulu ethnic population of around 217,750 individuals living in the Hlabisa sub-district reside in scattered, multigenerational homesteads of varying size (1-100 people) and there is substantial migration of people both within the area and to industrial towns and cities to seek work (Muhwava, 2007). The average household size within the DSA is seven individuals, which is almost double that of the rest of KwaZulu-Natal where the average is four and alongside this the average number of individuals aged under 18 in DSA households is three, a figure which appears to be increasing (Muhwava, 2008).

A cohort profile of the area found that between 2001 and 2006 access to piped water, electricity and sanitation in this rural area had increased substantially; 43-78%, 50-62% and 61-77% respectively (Tanser et al., 2008).

Demographic and HIV surveillance

The Demographic Surveillance Study (DSS) at the Africa Centre has been in operation since 2000 and the HIV surveillance since 2003, thus providing several rounds of data collection, which in turn provide longitudinal trends in mortality (both overall and cause specific) as well as HIV prevalence and incidence. All data collected are entered into a database known as the Africa Centre Demographic Information System (ACDIS).

In the Africa Centre DSA, demographic and economic data are collected from approximately 92,000 people (around 25,000 of whom are non-resident) in 11,000 households, twice yearly. Data collected include family structure, household socio-economic factors, household structure, child health (immunisations and birth history), births, deaths and migrations within families. In addition, all deaths are coded using a validated verbal autopsy instrument (Herbst et al., 2011).

The Africa Centre is situated in an area with a high HIV prevalence with findings from the Africa Centre showing that the overall HIV prevalence in the area amongst adults aged 15-54 years is 27% for women and 13.5% for men; with 51% of women aged 25-29 years and 44% of men aged 30-34 years being infected (Welz et al., 2007). More up-to-date findings from the Africa Centre indicate the overall HIV prevalence in 2011 to be 27.8% (26.6-29.0), however, based on the results of an imputation exercise the true HIV prevalence in adults is believed to be higher (Tanser et al., 2013).

Despite this high HIV prevalence and the corresponding common belief that HIV leads to high levels of underweight, a previous study by Barnighausen in this area (Barnighausen et al., 2007) showed that in 2006, despite the overall high prevalence of HIV within this population 27% and 13.5% in adult females and males respectively (but as high as 51% among women aged 25-29 years and 44% among resident men aged 30-34 years) (Welz et al., 2007), 58% of adults had BMIs which would classify them as being overweight, including 32% as obese (Barnighausen et al., 2007), therefore presenting a double burden of disease. A recent study also carried out in rural South Africa confirms the persistence of co-existing under and overnutrition in children and adolescents (Kimani-Murage, 2013). In the year 2000, HIV was the most common cause of death in the population of age 15 years and above (48% of all deaths), while cerebrovascular disease and heart disease jointly were the second most common cause (13% of all deaths)(Hosegood et al., 2004b). In a more recent study, Herbst et al investigated cause-specific mortality in this area between 2000-2009; HIV-related conditions accounted for 50% of all deaths and, with the exception of deaths categorised as indeterminate cause at 18%, non-communicable lifestyle-related conditions were the second most common cause accounting for 15% of all deaths. However when looking only at the 50-64 year age group, HIV related conditions accounted for 42% of deaths whilst this was followed closely by lifestyle-related non-communicable diseases at 27% (Herbst et al., 2011). A more recent study found that health care available to older adults who were HIV infected appeared to be better than that available to those uninfected and called for more holistic care to be accessible to all older people, focussed on all aspects of health and not simply on HIV (Nyirenda et al., 2012).

In 2010, the prevalence of HIV in adolescents resident within the DSA and in school grades 8 and 9 was found to be 3.2% for girls and 0.9% for boys (Graeme Hoddinott, personal communication).

Herbst et al found that the increase of mean age at death, between 2000-2006, from 36-40 years was largely attributable to availability of anti-retroviral therapy (ART) (Herbst, 2007). Survival appears to be increasing, individuals are often being able to return to work and studies in mothers and children showed that maternal survival leads to increased likelihood of child survival (Tanser et al., 2013, Bor et al., 2013, Ndirangu et al., 2012). Despite these positive findings there is no denying that HIV is still a major problem and has considerably increased mortality rates in the study population as well as significantly reducing life expectancy at birth (Tanser et al., 2008).

Geographic information system

There is a well established Geographic information system (GIS) at the Africa Centre. All homesteads within the DSS are mapped, as are other buildings (e.g., shops, schools, clinics) and amenities (e.g., local water supplies, rivers, roads) (Tanser and Le Sueur, 2002, Tanser et al., 2006).

Each homestead is given a unique identifier known as the Bounded Structure Identification (BSID) which is a 5 digit number between 10000 - 75000. Homesteads may consist of several different individual households and so within each homestead each household is given a Household Identification (HHID) (this can be a number between 2 - 5 digits from 10 - 25000). Further to this, each individual is given their own individual identifier known as the Demographic Surveillance Identification (DSID): this is a 5 letter identifier with the last two letters separated by a hyphen (e.g., DWXH-Z) (Table 4-1).

Table 4-1 Explanation of identifiers used in the ACDIS data

Identifier Name	Explanation	Code used	Example
Bounded structure identifier (BSID)	Identifies individual homesteads	5 digit number (ranging from approximately 10000-75000)	E.g., 31285
Household identifier (HHID)	Within homesteads, identifies individual households	Number between 10-25000	E.g., 617
Demographic surveillance identifier (DSID)	Identifies individuals	5 letters with the two final letters separated by a hyphen	E.g., DWXH-Z

4.1.3 Schooling in South Africa

School structure

Primary

Primary schools in South Africa begin at Grade R (Reception) for children aged approximately 7 years old then proceed from grade 1 up to grade 7. Primary schools vary in their structure and are of two different types – Some are comprised of all grades R-7, whereas others (the majority) tend to be split into separate lower and upper primary schools with lower primaries being comprised of children in Grade R-3 and upper primary having children in Grades 4-7. Where the latter structure is the case, the two schools are often located close to each other but are different buildings run by separate prinicipals (i.e. head teachers) and with different educators (i.e. teachers).

Secondary

Secondary schools include grades 8-12 with matriculation exams (school exit examination) taking place in grade 12 at approximately 18 years of age.

School quintiles/classification

As a result of educational policy change in 2006, each school was allocated a quintile (Consortium for Research on Educational Access, 2009). There are 5 quintiles/classes of schools in South Africa, quintile 1 schools being most deprived and quintile 5 least deprived. These allocations are based on rates of income, unemployment and illiteracy within the school catchment area (Consortium for Research on Educational Access, 2009).

Quintiles 1 - 3 are 'no fee' schools and quintile 4 and 5 are fee paying. As shown in Table 4-2, quintile 1 - 3 receive 100% of their funds from the government, quintile 4 receives 67% and quintile 5 receives 22% with the remainder being subsidised by fees or from other sources.

Table 4-2 Funding allocation based on school quintile classification

Quintile	Government contribution	Annual per learner allocation (2010)	National % per quintile	Provincial % per quintile KZN*
1	100%	ZAR 855	30.0	24.2
2	100%	ZAR 784	27.5	18.8
3	100%	ZAR 641	22.5	25.6
4	67%	ZAR 428	15.0	17.3
5	22%	ZAR 147	5.0	14.1

1 South African Rand (ZAR) = 0.085 Great British Pound (GBP) as at 28 February 2010 (Education, 2010).

*KZN = KwaZulu- Natal

A quintile 1 allocation of 24.2% ranks KwaZulu Natal as 5th poorest out of the 9 provinces with Eastern Cape identified as the poorest (34.8% of schools in quintile 1) and Western Cape least poor with only 6.5% of schools in quintile 1 (ACTS, 2010).

Enrolment and attendance of learners

For a vast number of reasons, children and adolescent's attendance at school can be very poor and sporadic, with long periods of non-attendance or attendance of only a few days a week. Many children also move school several times during their education. Age range within grades can vary extensively and it would not be uncommon to find an individual in Grade 1 who is 13 years old or a Grade 12 (matriculation) student aged around 25 years old.

Studies examining reasons for learners' non-attendance in South African schools found poverty to be the main factor (Fleisch, 2010, Porteus et al., 2000). However, many other contributing factors were also found, these included the individual's health, disability or pregnancy, high levels of migration between areas, alongside children's lack of the appropriate documentation required to enrol in school (i.e. birth certificate) and lack of family support and encouragement to attend. School-related factors included inability to pay fees, no provision for mid-term entry or lack of places (Porteus et al., 2000, Fleisch, 2010).

Distance to school is another important factor, with ‘access to school’ statistics from 2002 showing that over 8 million learners across South Africa resided beyond a 5km radius from their school (Veriava, 2005). As suggested above, within the Africa Centre DSA there is substantial migration of families into and out of the district which may mean learners move away from their school area completely at some points during term time (Muhwava, 2007). The high levels of migration are often a result of mortality within the family and can essentially lead to breakdown of the family unit especially in poorer households (Hosegood et al., 2004a). Findings have also shown in-migrants to be at higher risk of dying from HIV-related causes (Welaga et al., 2009).

Sporadic attendances for the above variety of reasons can lead to learners constantly failing exams and therefore repeating grades, leading to a later school leaving age.

Under the South African Schools Act 1996, schooling was made compulsory up to age 15 years or until the completion of school grade 9, whichever comes first (Department of Education, 1996). Recent UNICEF statistics state primary school net enrolment rates between 2005-2009 to be 87% (UNICEF, 2010).

Enrolment is often declared as an indicator of access to education, however, this of course does not necessarily reflect actual attendance. National data from the General Household Survey (GHS in 2006 found that despite almost full enrolment rates, 200,000 children in the 7 - 15 year age group do not attend school regularly. Enrolment figures decline rapidly to around 83.1% after the compulsory education period is completed in grade 9 or at age 15 years.

A survey conducted within the Africa Centre DSA found that 6.5% of learners on the class registers were not actually eligible to attend that school for reasons such as they had moved elsewhere, were registered under two different names or had in fact passed away (Graeme Hoddinott, personal communication). Results showed 4.1% of eligible learners did not attend school on any of the five (average) days that the survey team visited the school (Graeme Hoddinott, personal communication). Estimations from process indicators suggest that on normal school days the vast majority of learners do attend school (reasonable allowances made for illness), but that major interruptions to school attendance (heavy rain, strikes, cultural days) occur regularly.

Matriculation pass rate

In the late 1990s the national matriculation pass rate was extremely low at merely 40%, however this has greatly improved with a total of 61% passing matriculation exams in 2009, and increasing even further to 68% in 2010 (Department of Education, 2011). Looking at the results from a provincial perspective, KwaZulu-Natal achieved a 71% pass rate in 2010 (up from 61% in 2009).

Although examination pass rates are improving, illiteracy remains a considerable issue with over 18% of adults over 15 years of age (9 million) not functionally literate in South Africa and many teachers in township schools still poorly trained (Department of Education, 2011).

School year

Teaching time in public sector institutions tends to be regularly disturbed for a variety of reasons.

Alongside the allotted school holidays other reasons for school closure or learners non-attendance at school include: extra public holidays, parents keeping them home from school to do household work, heavy rains which can make roads impassable, school strikes, holidays starting early i.e. teachers may cut their teaching programme a few weeks before the end of term.

The year in which this study took place (2010) was also the year that South Africa hosted the football World Cup and so official term time was changed to give school children extra holidays allowing schools to shut for the entirety of the event. Instead of the three weeks of holiday learners would normally receive in June-July they actually had four weeks.

School feeding programme

Officially called the National Schools Nutrition Programme (NSNP)(Sangweni, 2008), this is part of the Integrated Food Security Strategy for South Africa introduced in 2002 and has the following four aims:

- Enhancing children's active learning capacity
- Alleviating short term hunger
- Providing an incentive for children to attend school regularly and punctually
- Addressing certain micro-nutrient deficiencies

Eligibility

The selection process for eligibility has two different phases

- Firstly, whole schools are selected for funding on the basis that they are in poor areas and therefore the majority of their learners are from poor families.
- Secondly, learners within these schools are selected using certain criteria, e.g, age or grade.

Provision

Guidelines state that children who are eligible should be provided with one meal or snack a day, by 10am, through one of the 22 nutritionally approved menu options (DOE, 2012).

4.2 Ethical approval and additional permissions required for the current studies

Figure 4-5 shows the process conducted to gain ethical consent for the present study (see Appendix 4 for evidence of biomedical ethical approval obtained for the present study from the University of KwaZulu-Natal (UKZN) biomedical research ethics committee (BREC) (ethics reference: *BE028/010))*.

Community advisory board

The Africa Centre community advisory board (CAB) is a group of 40 individuals selected from the local community. Members are of varying levels of education and knowledge and their purpose is to provide a representative decision on whether proposed projects in the Africa Centre area should be allowed to proceed. A powerpoint presentation was made to this board, followed by a question time to allow them to make their decision on the present study. The present study was approved by the CAB on 25 Feb 2010 with no queries or questions raised by any of the members.

A presentation was also made to the CAB at a later date to explain the progression of the study, show them the equipment and allow them to have their own measurements taken so they were familiar with the procedures involved.

Department of Education

Following two visits and a full explanation of the study both orally and by letter, permission was granted, to carry out this study in schools, from the Department of Education, at district level (by Mr Mngomezulu - Chief Education Specialist, Hlabisa, 19 March 2010) *(see Appendix 5)*

Initial ethics submission to University of KwaZulu-Natal (UKZN) Biomedical Research Ethics Committee (BREC) - secondary school arm of cross-sectional study (8 Feb 2010)

↓

Provisional approval pending response to queries received from UKZN Biomedical Research Ethics Committee (BREC) (25 March 2010)

↓

Response to queries sent to BREC (26 March 2010)

↓

Submission of amendments to BREC to include primary school cross-sectional and full sub-sample study (1 April 2010)

↓

Queries to amendments received from BREC (26 April 2010)

↓

Response to queries regarding amendments sent to BREC (3 May 2010)

↓

Full approval received from BREC (21 June 2010)

Italics=Correspondence to BREC
Bold= Correspondence from BREC

Figure 4-5 Ethical process for present study

4.3 Part 1 – Cross-sectional study of prevalence and correlates

Children and adolescents from school grades 1, 5 and 9 (approx ages 7, 11 and 15 years) were recruited from local primary and secondary schools within the Africa Centre DSA in the Hlabisa sub-district, a rural area of the KwaZulu-Natal Province of South Africa. All schools which participated were within the DSA. Based on the power calculation for this study, I aimed to recruit an overall sample size of 1,500 (500 from each school grade).

4.3.1 Main sample for prevalence and correlates study

Study participants were recruited and measured between April 2010 and December 2010.

Inclusion criteria

i. Participants to be of Zulu origin

ii. To be enrolled in school grade 1, 5 or 9.

In addition to this, signed informed consent must have been obtained from their caregiver and assent from themselves before they could take part. It was also necessary that they were in attendance at school on the scheduled day of assessment. Disease state and HIV status of participants were **not** noted.

Exclusion criteria

i. Children not enrolled into school grade 1, 5 or 9 despite being of an appropriate age

ii. No signed consent provided by parent or caregiver.

4.3.2 School selection method for main sample

Secondary schools (see Appendix 6)

The aim was to recruit 500 adolescents aged approximately 15 years old from local secondary schools.

In this phase of the study schools were chosen, taking into consideration their location within the DSA, with regards to rural or peri-urban status (proximity to roads, and access to electricity) and also by choosing at least one school from each of the school quintiles present within the area. As described in the ‘school structure’ section (4.1.3) previously in this chapter, these quintiles are representative of school wealth and discern how much funding schools receive per learner. Quintiles 1 - 3 are ‘no fee’ schools and quintiles 4 and 5 are fee paying schools. There were no quintile 5 schools in the study area. This method of school selection, in order to obtain a representative sample, has been used previously in the South Africa Health of the Nation Study (Armstrong et al., 2006).

The schools recruited into the study encompass a broad range of areas to ensure the sample was representative, i.e. some schools were close to town and had a high enrollment of learners, while others were more rural with smaller numbers enrolled, all of which were within the DSA.

Primary schools (see Appendix 7)

The aim was to recruit a further 1,000 children from primary schools in the local area; 500 from Grade 5, (aged approximately 11 years old) and 500 from Grade 1 (aged approximately 7 years old).

Due to the unbalanced number of primary schools in each quintile (i.e. most primary schools are in quintile 3), quintiles were not used as a selecting factor in this phase and instead primary schools were chosen at random by using the randomisation function in excel (‘=rand()’) which allocates a random number to each school in the list. Schools were then sorted, using that number, from smallest to largest. This randomly ordered list was to be worked through until the sample size reached at least 500 in each grade. (This randomisation procedure was also the process used for the sub-sample study which is explained in section 4.4)

As previously described, primary schools in South Africa vary in their structure and are of two different types – some are comprised of all Grades R-7, whereas others (the majority) tend to be split into separate lower and upper primary schools with lower primaries having children in Grade R-3 and upper primary having children in grades 4-7. Lower and upper primaries are often located close to each other but not in all cases. If an upper primary school was chosen by randomisation the lower primary school which was (linked) next to it would also be visited.

4.3.3 Consent - school and individual

School consent

Schools were initially invited to participate by arranging a meeting with the principal where the study was explained and letters of information were distributed *(see Appendix 8)*. Following explanation to the principal and consent being granted for the study to be conducted during school hours, educators (teachers) from the specified grade were also approached to advise them of the study procedures.

Parental and learner consent

Following initial consent from the principal for the school to participate in the study, a second visit was made to schools in order to explain the study to learners. At this time information and consent forms were distributed to all learners in the specified grade so they could take them home to parents, decide whether they wished to participate and gain consent *(see Appendix 9)*. The explanation process took around 20 minutes per classroom (in some schools one grade was split across several different classes, e.g, if there were 250 in Grade 1 there would usually be 5 classes of 50) and was carried out in Zulu by a native Zulu speaking fieldworker. The study was firstly explained informally to the learners to ensure they understood what the study involved, they were then given their consent forms and this was read out and explained to them, showing where the form needed to be signed. Learners were also asked to provide their Bounded structure identification (BSID) number on the form, this is a 5 digit number assigned to them by the Africa Centre and placed on a small plaque on the outside of each house within the DSA (see section 4.1.2 and Table 4-1 for further information on bounded structures). Five boxes were placed on the form for learners to enter this information, this was also explained to them, ensuring they knew what their BSID was, and indicating where they should enter it.

Informed consent was obtained from parents or guardians and assent from the subjects themselves. The following week another visit was made and those with completed consent forms were eligible to participate in the study. If a BSID was not provided but consent was obtained the learner could still take part in the study.

Consent forms were stapled to the information form at the time of questionnaire administration.

4.3.4 Subject identification

Each participant in the study was given their own unique 'StudyID'. This was a 4 digit number from 0001-1500. Grade 9 was the first 500 (0001-0500), Grade 5 the next 500 (0501-1000) and Grade 1 the last 500 (1000-1500). When there were more than 500 measured in any particular grade the extra participants were given a number above 1,500 e.g., 1501, 1502 etc.

4.3.5 Study protocol

The cross-sectional study involved an interviewer-administered questionnaire, as well as anthropometric measurements.

Questionnaire (see Appendix 10)

The questionnaire was split into two parts: personal details and lifestyle questions

- Personal details

Participants were initially asked personal details such as date of birth, age, full name as well as mother's and father's names. If provided on the consent form, BSID was also noted at this point.

- Lifestyle questions

Participants were then also asked a short questionnaire about their daily activities such as collecting water, method of travel to school, TV watching and any sports in which they participated.

This was a self-designed questionnaire, asking questions the author felt would help to indicate risk factors and also using information from other studies including a study carried out in a similar population in Mozambique, the results of which were compared to children living in Portugal (Prista et al., 2009).

Anthropometric measurements

Children then moved through three different stations which had been set up around the room. At each station a trained fieldworker carried out anthropometric measurements including mid-upper arm circumference (MUAC) (cm), height (cm), weight (kg) and body fat (%). Each measurement was carried out twice, except weight and body fat as digital scales were used for this and results were written on a standard data form. A description of each measure is given below and details of standard operating procedures (SOPs) for each measure can be found in the appendices noted.

Mid-upper arm circumference (MUAC) (see Appendix 11)

MUAC was measured using a non-elastic measuring tape (Chasmors, London). Subjects were told in advance to have clothing which allowed us to access their full left arm up to shoulder point, i.e. a loose fitting t-shirt or vest under their school shirt.

In adherence to WHO standards the left arm was always used (de Onis et al., 2004b). Firstly, the mid-point of the arm was ascertained by measuring from the acromion process (back of shoulder bone) down to the olecranon process (tip of the elbow), while the arm was held at a 90º angle, palms facing up. The resulting figure was divided by two and the halfway point was marked with a washable marker. (A sheet showing the divided number was available for the fieldworker to check with at any point in order to avoid risk of manual calculation error, Table 4-3).

Table 4-3 Example section of sheet provided to fieldworker for purposes of MUAC measurement

15 ÷ 2 =	7.5
16 ÷ 2 =	8.0
17 ÷ 2 =	8.5
18 ÷ 2 =	9.0
…	….

The subject was then asked to drop their left arm down by the side of their body and tapes were passed around the arm at the marked point. The point at which the tape overlapped the zero mark was recorded to the nearest 0.1mm and the measurement was then carried out a second time ensuring the two separate measurements were within 4mm of each other (Ozturk et al., 2009, Moreno et al., 2006).

Height (see Appendix 12)

Height was measured to the nearest 0.1cm using a SECA scale stadiometer. As per WHO guidelines (de Onis et al., 2004b), the subject stood barefoot on the foot platform; feet flat, legs straight, back of head/shoulder blades/buttocks/calves and heels as near to, or touching the vertical board, eyes looking straight ahead in Frankfort plane and arms/shoulders relaxed. The subject was instructed to take a natural breath in and the headboard was pulled down to take a reading - recording the figure at which the arrow was pointing to. The subject was then asked to step off the foot platform and then back on reassuming the same position. The maximum allowable difference between the replicate measurements was 5mm, if this was not achieved measurements were carried out again.

Weight/body fat/total body water (See Appendix 13)

Weight was measured and body fat and total body water (TBW) were estimated using bio-impedance scales (Tanita SC240MA). 'Non-athlete' was chosen as standard and a standard 0.5kg was deducted for all subjects to account for clothes weight. Prior to the subject stepping on to the scales: gender, age (years) and height (to nearest cm) were entered, when prompted by the flashing display. When the device displayed the 'Step On' command, subjects were instructed to step on to the 4 round electrical plates, with their toes on the front two and their heels on the back two.

Readings given by the Tanita were weight, % body fat, %TBW and BMI (all displayed to one decimal point). Body weight was measured to the nearest 0.1kg and body fat and total body water estimated to nearest 0.1%.

Body mass index (BMI)

BMI readings given by the Tanita were noted but not used; instead this value was calculated independently from individual height and weight measurements. Body mass index was calculated as weight (kilograms) divided by height (metres) squared (kg/m^2).

The whole process of questionnaire administration and anthropometric measurements took around 15 - 20 minutes per subject. Each subject was shown on a standard growth chart where their weight, height and % body fat fell as well as being given a copy of their measurements to take home with them (see Appendix 14) and a short pamphlet from the Department of Health entitled ‘Healthy living is the way to go’ (see Appendix 15).

As a token of our appreciation for subjects participating, and due to the fact that measurements were often carried out over school break time, each child was also given an apple upon completion.

4.3.6 Data entry

Access database

An access database was developed by the author (EC) with guidance from the Africa Centre database scientist, for input of all data from the prevalence study. Adequate constraints were placed on this database in order to minimise the possibility of input errors. All data were entered by the author and on completion the author also cross checked 10% of all entries to ensure accuracy was adequate.

The time taken to enter the information for each subject was around four minutes per subject (4 minutes x 1,500 subjects = 6,000 minutes = 100 hours).

ACDIS matching

The access database was also linked to a matching tool, using information from the Africa Centre Demographic Information System (ACDIS). This tool was used in order to allow each participant to be linked with their Bounded Structure Identifier (BSID) and also their own individual Demographic Surveillance Identification (DSID). This was designed by the database manager and allowed both searching of BSIDs which were not already provided by individuals as well as confirming that those BSIDs provided were indeed correct. The matching tool was linked to the access database with the ability to search for any individual present within the ACDIS datasets, on the basis of name, date of birth, sex, mother's and father's names and head of household name.

To refine the parameters of the search only children born between '1 Jan 1980' and '31 Dec 2005' were included in the matching tool.

The matching process was carried out by the author (EC) and involved manually going through each subject's details and using each/all of the variables in turn to determine which one matched the subject until a best match was determined. Some subjects were matched very quickly and easily, whereas for others it took many attempts and lengthy periods of time *(see Appendix 16)*.

Anthroplus

In order to work out z-scores for each individual, all necessary data - namely children's names, date of birth, visit date, height and weight - were entered into the WHO AnthroPlus programme (WHO, 2009c). Anthroplus is software which has been designed to allow global application of the WHO Reference 2007 for children aged 5 - 19 years to monitor the growth of school-age children and adolescents (WHO, 2007, WHO, 2009c). Output of the following z-scores is given: weight-for-age, height-for-age and BMI-for-age. The output of height-for-age and BMI-for age z-scores were used.

This is a WHO programme and as the WHO weight-for-age references are only available for children up until 10 years old (WHO, 2007) a weight-for-age value was only given if the child was ≤10 years old. The present study included subjects older than 10 years of age and therefore a different reference was used to provide weight for age results for all subjects (see section below entitled EpiInfo CDC).

The time taken to enter each subject's details was around two minutes per subject (2 minutes x 1500 subjects = 3000 minutes = 50 hours)

Cole/IOTF cut points

For calculation of Cole/IOTF cut points it was possible to use the Microsoft Excel output of values entered for Anthroplus: age (generated by date of birth and visit date), sex, weight and height, in order to generate an output of the Cole SDS scores using a Microsoft Excel add-in designed specifically for this purpose (Cole et al., 2000, Cole et al., 2007, Cole, 1990, Harlow Healthcare, 2000).

EpiInfo CDC

As described above, WHO weight-for-age references are only available up to age 10 years, therefore the EpiInfo Nutrition programme available from the Centre for Diseases Control and Prevention (CDC) was used to calculate weight-for-age for all children using the CDC growth reference charts (CDC, 2008). Subject's ID number, sex, age, height and weight were all entered into the program to allow output of the necessary information. Many variables were produced, however, for the purposes of this study fldWHOWAZ was the weight-for-age variable used.

4.4 Part 2 – Sub-sample exploring characteristics of physical activity and diet

Based on figures from a power calculation (See Chapter 2: Aims), a randomly generated sub-sample of 150 young persons (50 from each grade 1, 5 and 9) were invited to take part in a smaller, more in-depth study which comprised two parts. The sample of 50 learners from each grade was randomly generated by computer selection using Microsoft Excel. Learner's unique study ID, assigned to them in Part 1 of the study, was used to randomise using Microsoft Excel (as described previously for primary school selection in the cross-sectional study see section 4.3.2).

Dietary assessment (using a 24 hour dietary recall technique) and objectively measured physical activity/sedentary behaviour (using 7 days of accelerometry measurement) were carried out on all participants who consented to take part in this study.

4.4.1 Consent process for sub-sample study

Due to the nature of the data to be collected in the sub-sample and the differing age of subjects in the separate grades, the consent forms and the process of consent was slightly different for grade 1 compared to that for grades 5 and 9.

Learners in grades 5 and 9 had the consent form explained to them at school and were then given the consent form which required parental and learner consent *(see Appendix 17)*. A subsequent visit was made to the school on a separate day to collect the consent form and carry out the sub-sample study at school.

Learners in grade 1 were also given the consent form at school, however, due to their young age, it was required that they had parental assistance during the process of the sub-sample study and therefore were to be visited in their own homes. The consent form was amended to include sections allowing parents to give us physical directions to their home and also their cell number (mobile phone number) in the event we needed to contact them *(see Appendix 17)*. They were also encouraged to give us their BSID again so we could confirm which house to go to and could determine where exactly this was, using the Africa Centre Demographic Surveillance week block maps used in Africa Centre fieldwork *(see Appendix 18)*. A second visit was made to school to collect this form from learners at which point the learners were given a note to give to their parents detailing which day we would make our visit to their home. In this part of the study all such visits needed to be made after school hours when children were at home.

4.4.2 Dietary assessment

24 hour multiple pass recall

Taking into consideration a variety of factors relevant to the purposes of the study, such as age of participants, subject burden and practicality, 24 hour multiple pass recall (a variation of 24 hour recall as previously explained in Chapter 3 – Justification of Methods) was the dietary assessment method chosen as the most appropriate. This is an interviewer-administered subjective retrospective method of dietary assessment whereby participants have to think back over everything they have eaten and drunk in the previous 24 hours and give a detailed description of each item with help and prompting from the interviewer to encourage the most accurate recollection possible (Burrows et al., 2010, Johnson et al., 1996).

Layout

All food and drink eaten on the previous day was recorded. This technique is given the name multiple pass as it involves asking similar questions in several different sweeps or 'passes' in order to reduce the tendency of individuals to forget foods or drinks they had consumed.

The 24 hour recall used here had 4 steps, shown below in Figure 4-7.

STEP 1
General idea of foods and drinks:
Learner thinks and recalls all foods eaten on the previous day, regardless of time and order. Interviewer makes a list.

⇩

STEP 2
Remembering forgotten items:
Interviewer goes through a list of things often forgotten, *eg. Did you eat any cakes or bread etc?*

⇩

STEP 3
Detail about each food and drink item:
Time eaten, description of the item, its preparation and portion size using Food Photo Manual.

⇩

STEP 4
Last attempt to identify any final forgotten things:
Ask subject to think back one last time, look back over food photo manual and also read over the list of items reported so far.

Figure 4-7 24 hour recall procedure used in present study

Details were also taken for type of milk, margarine and oil usually used in the home.

An exact dialogue for the interview was compiled by the author (EC) for the Zulu trained nutritionist to follow (see section 4.5 below for further details on staff), this would ensure the same protocol was followed in every interview *(see Appendix 19).* A standardised form was also provided for recording all information collected *(see Appendix 20).*

The protocol of the 24 hour recall used was adapted from the South African MRC and has been used previously in South Africa (Rankin et al., 2011b). It was used in conjunction with the Dietary Assessment and Education Tool (DAEK).The DAEK consists of 400 colour photographs of foods and food products commonly consumed by South Africans. There are also 15 cards containing generic life size drawings of portion sizes and volume measures to assist participants in their estimation. This tool has previously been validated for use in South African adolescents where black adolescents were in fact found to estimate more accurately than white adolescents (Steyn et al., 2006)*(see Appendix 21).*

24hour recall protocol

The 24 hour dietary recall in the present study was administered to each participant on 2 separate occasions, on non consecutive days (at the beginning and end of the 7 day accelerometry).

Where a child was absent when we returned for the second dietary assessment and to pick up the accelerometer, we visited the school again on another day when the child was present and until both assessments were completed. An example of the sub-sample process is shown in Figure 4.8.

Mon	Accelerometer given / dietary recall of Sunday
Tue	Day 1 Accelerometry
Wed	Day 2 Accelerometry
Thu	Day 3 Accelerometry
Fri	Day 4 Accelerometry
Sat	Day 5 Accelerometry
Sun	Day 6 Accelerometry
Mon	Day 7 Accelerometry
Tue	Accelerometer collected / dietary recall of Monday

Figure 4-8 Example of sub-sample protocol

At least six days separated each interview in order to minimise the effect of memory on participants answers. Although it would have been ideal it was not always possible to make a recording of a weekend day.

Nutritional analysis

All data collected were entered into a nutritional analysis program FoodFinder 3. This is software developed by the Nutritional Intervention Research Unit (NIRU) and Biomedical Informatics Research Division (BIRD) of the South African Medical Research Council

(MRC)(MRC, 2002). This program has been developed for South Africans, and can be used for the analysis of food intake of individuals or groups of individuals *(see Appendix 22)*.

A previous study conducted in this area, also at the Africa Centre, (Herbst, 2008) had identified 'usual' composition of traditional dishes by several repeat preparations of the dishes along with weighing of ingredients and determination of average serving size; a total of 48 recipes were developed in this way. These data were entered into FoodFinder3 as complete recipes, adding strength to the accuracy of the data entered in the present study.

4.4.3 Physical activity assessment

Accelerometry

Accelerometry is a technique which produces an objective measure of both physical activity and sedentary behaviour by measuring an object's acceleration.

Acceleration = Rate of change of velocity/time

Accelerometers are devices which measure body movements in terms of acceleration, recording all data in counts. The total counts measured give an overall volume of total activity, however, when the intensity of activity is of interest these counts can be further separated into epochs (intervals). Dividing counts into these epochs allows physical activity intensity at certain times during the measurement period to be determined enabling an estimation of physical activity intensity over time and so energy expenditure (Chen and Bassett, 2005). Common epochs used range from 5 - 60 seconds and choice of epoch will depend upon study population and aim of the study, for example, in very young children a shorter epoch may be chosen, as at this age activity tends to be sporadic and performed in bursts, whereas in an elderly individual a longer epoch may be chosen, as activities tend to be done over a longer period of time (Ward et al., 2005).

In order to distinguish different intensities there must be predetermined cut points for defining these intensities. Intensities of physical activity are usually defined as sedentary, light, moderate and vigorous. Many different cut points have been published over the years and a range for different intensities is shown in Table 4-4 below. As can be seen from the table, with the exception of the Puyau cut points, published cut points for sedentary and light intensity activities do not vary greatly (≤100 and ≥100 for sedentary and light intensity activity respectively) however there is substantial variation between cut points defining moderate and vigorous activities (between ≥2220 and ≥3581 for moderate and between ≥4136 and ≥8200 for vigorous). Decision on the cut point to be used can have a significant effect on results. Given that physical activity recommendations tend to be based on levels of moderate - vigorous physical activity it is crucial that cut points are chosen carefully to maximise accuracy and allow comparisons to be made between studies (Trost et al., 2010). A review carried out by Trost et al concluded that Evenson cut points were most accurate in classifying physical activity intensity of children and adolescents between 5 and 15 years of age (Trost et al., 2010). In the present study two different sets of published cut points were used (Puyau and Evenson) and a comparison of differences was made during analysis (see Chapter 7: Lifestyle, Physical Activity and Diet).

Table 4-4 Published cut points for physical activity intensity in children and adolescents (Adapted from Trost et al (Trost et al., 2010))

Author of cut point	Sedentary	Light	Moderate	Vigorous
Freedson et al	≤100	≥100	≥2220	≥4136
Puyau et al	≤800	≥800	≥3200	≥8200
Treuth et al	≤100	≥100	≥3000	≥5200
Mattocks et al	≤100	≥100	≥3581	≥6130
Evenson et al	≤100	≥100	≥2296	≥4012

All cut points are shown in counts per minute.

The GT3X Actigraph accelerometer was used in this study (Figure 4.9). This was the latest accelerometer available from Actigraph at the time of data collection (the GT3X+ has since been launched) and was their first triaxial accelerometer (measuring acceleration in 3 planes anterioposterior (back to front), mediolateral (side to side) and vertical (up and down)).

Figure 4-9 Actigraph GT3X Accelerometer shown here next to a UK 50p coin to give an indication of size

Programming

Accelerometers are programmed to collect data via a USB and by use of the Actilife software which has been designed specifically for them (www.theactigraph.com/products/actilife/). This programming is done prior to distribution to the subjects. The author (EC) was trained by a specialist in this area and the procedure for programming was as follows:

1. **Connect** accelerometer via USB.
2. Ensure fully **charged**
3. Select **initialize device**
4. **Check boxes marked**
    - Activity
    - Enable stop time
    - Dual axis
    - 3rd axis
    - Inclinometer
5. **Select**
    - Epoch length 15 sec
    - Start date/time
    - End date/time
6. **Enter** ID as subject's first initial/surname/4 digit study ID, e.g., JSmith0105

Figure 4-10 Programming procedure for GT3X accelerometer

The serial number shown on the back of the accelerometer was entered onto a sheet next to the individual's ID so that at the time of collection it could be confirmed that it was returned by the same individual and that the subjects had not swapped devices.

Accelerometers were programmed (Figure 4-10) to begin collecting data at 00.00 hours on the day following the first 24 hour recall and to stop collecting data exactly 7 days later at 00.00hours. This was to ensure seven full days of data were collected.

Once the accelerometer was initialised the device would flash every 2 seconds until it began collecting data, at which point the flashing would cease and there would be no visible sign on the device. Subjects were instructed that this would happen in case they thought their device had stopped working.

There are no buttons on the device and it cannot be switched on or off by subjects, therefore preventing possibility of tampering with collection details.

Accelerometry protocol

Accelerometers were given to children after the initial 24 hour dietary recall interview. Method of wear was explained to participants along with a full demonstration. Participants were instructed to:

- Place the activity belt around their waist so that it was on their right hip, under their clothes.
- Make sure they had it on the right way round with the A of the Actigraph symbol pointing towards their head and the black rubber (cover of the USB port) on the left hand side of the device.
- Adjust the elastic to make sure the belt was secure and comfortable.

Learners were also given a sheet with instructions for wear and an activity log sheet running from 5am - 12 midnight, for the full 7 days (Fisher et al., 2005) *(see Appendix 23)*.

They were asked to record the times when they put it 'on' and took if 'off' in the activity log sheet each day. If there were any other activities or time periods which they wished to make note of they were encouraged to do so in order to help in the analysis (i.e. vigorous exercise, long periods of sedentary behaviour or times when the accelerometer was removed for bathing or swimming), however, there was no requirement for this to be done.

Accelerometer downloading

When the accelerometer was collected in from subjects the data were downloaded to Actilife. This automatically creates .csv and .dat files which would be used for analysis. The accelerometer was then recharged ready for its next use.

Accelerometer data handling

The .dat file is not used and cannot actually be viewed but provides a pathway to access the .csv file. The .csv file (Figure 4-11) shows date and time (in 15 second epochs), counts for the three different axis of accelerometry, plus an integrated reading. There is also an inclinometer which notes posture (sitting, standing, lying).

Inclinometer readings were as follows

0 = Device is off (not being worn by the subject)

1 = Subject standing

2 = Subject is lying horizontally

3 = Subject is sitting upright

Date	Time	Activity	Activity (Horizontal)	3rd Axis	Vector Magnitude	Inclinometer
2010/11/03	14:13:30	20	145	306	339.2064	1
2010/11/03	14:13:45	0	34	105	110.3676	1
2010/11/03	14:14:00	0	121	45	129.0969	1
2010/11/03	14:14:15	0	66	12	67.08204	1
2010/11/03	14:14:30	359	412	544	771.0778	1
2010/11/03	14:14:45	887	947	561	1413.612	1
2010/11/03	14:15:00	57	94	175	206.664	1

Figure 4-11 Example of .csv output from GT3X Accelerometer

The .csv file was copied to a predesigned MS Excel template for analysis. Each days of data from 05.00 to 00.00 was copied into its own individual day i.e. Day 1, 2, 3 etc; these data were then automatically transferred into a spreadsheet which calculated single axis (uniaxial) data and also one for integrated (triaxial) data. Each single and integrated day then needed to be amended to match exact hours worn, e.g.,, if only worn for part of an hour the minutes worn and formula used for that hour needed to be changed. The final spreadsheet was a summary of all seven days activity. This analysis was a lengthy process and depending on the individual’s pattern of wear could take between 45 minutes and 2 hours per subject.

Based on previous evidence, at least 3 days’ wear with at least 6 hours on each day were required for data to be considered at a standard useable for analysis (Penpraze, 2006). The accelerometry results from the present study are presented and discussed in Chapter 7: Lifestyle, Physical Activity and Diet.

4.5 Requirements for and roles of additional field staff

As the study took place in rural KwaZulu-Natal, an area where the native language is isiZulu and the majority of children and adolescents have relatively low levels of spoken English it was necessary to recruit fieldworkers who were native isiZulu speakers and could therefore effectively describe the studies to the learners, and carry out the lifestyle questionnaire and dietary assessment in a language the children would understand. In addition to the recruitment of native fieldworkers, all information sheets were also translated into isiZulu. Another reason for recruiting fieldworkers was to minimise disruption of learners' class time and to ensure the study was completed in the most efficient way. Multiple fieldworkers also meant that each individual could focus on one specific measurement/task.

Staff assisting with main sample for study of overweight and obesity prevalence, correlates and lifestyle data

Fieldworkers were recruited from the Africa Centre 'supply list'. This list consists of individuals who have all been trained in basic research methodology and data collection for the Africa Centre DSS who can be employed to work on any Africa Centre projects. All staff on this list have achieved education to matriculation level (school exit exam) but do not have tertiary education. Three were called for interview based on the English/Maths scores they had previously achieved in the introductory test carried out by Africa Centre, as these attributes were an important aspect of the job. Interviews consisted of informal questions to the candidates to determine suitability for the role and grasp of English, maths-based questions to test suitability for involvement in measurement techniques and a practical test of equipment use. Each technique to be used in the study was briefly explained and practically demonstrated to the interviewee and they were then asked to carry out measurements independently. Of the three called for interview, two were chosen to assist the author in carrying out the study, on educational grounds but also because they were enthusiastic about the job and enjoyed working with children.

Fieldworkers attended 2 full days' training, led by the author (EC), and had hands-on experience of the techniques prior to visiting the schools. Training involved watching the 'WHO Multicentre Growth Reference' and 'Anthropometry Training' DVDs, a full demonstration and run through of Standard Operating Procedures (SOPs) for each measure as well as carrying out measurements on each other and on other staff at the Africa Centre.

Exercises looking at example cases were conducted to ensure they could recognise outliers and incorrect measurements, and have a general mental image of an individual simply by looking at their measurements.

Accuracy was emphasised and it was made clear that replicate measurements must be within the limits set by the WHO, e.g., 4mm for MUAC and 5mm for height. If subsequent measurements were not within these limits they were to be repeated.

Administration of the questionnaire was also practised so fieldworkers could become familiar with the questions and any skips which were attached to questions, e.g., if 'No' go to Q3.

Staff assisting with sub-sample study for investigating characteristics of physical activity and diet

The procedures to be undertaken in the sub-sample required a trained interviewer and in this instance needed to be carried out in Zulu. After a Curriculum Vitae (CV) review and on completion of an interview, conducted by Dr Ruth Bland and the Author (EC), an individual was chosen for this role. This individual had completed a Consumer Science degree (which is primarily a nutrition-based degree), was specifically trained in conducting 24 hour dietary recall prior to the commencement of the study and was a native Zulu.

Prior to the fieldwork commencing, practice interviews were conducted on colleagues at the Africa Centre as well as young children, to allow us to estimate time taken and note any problems which arose with the questionnaire.

The recruited staff member was fully acquainted with the computer software to be used throughout the course of the sub-sample study, namely Actigraph (for accelerometry) and FoodFinder3 (for dietary assessment), this training was given by the author (EC).

4.6 Africa Centre variables chosen from the Demographic Surveillance database to allow analyses of anthropometric risk factors

Variables in the Africa Centre datasets were chosen if they were thought to be potentially associated with being overweight or obese. Information from recent reviews was examined for variables believed to be important to obesity risk (Reilly, 2006a, Monasta et al., 2010, Parsons et al., 1999, Yang et al., 2008, Sousa, 2009, Kimani-Murage et al., 2011). The study was dependent on information already available in the ACDIS database and therefore all variables were chosen which had (a) arisen in reviews and which (b) were available in ACDIS. These variables came from several different Africa Centre datasets and related to socio-economic, individual, geographic and maternal information. These included variables such as water source, household assets, mothers education level and employment etc (see Table 4-5).

Table 4-5 Africa Centre datasets and specific variables chosen from each

DATASETS			
ACDIS*	***CORE****	***Geographic information system (GIS)***	***Maternal information***
Drinking water source	Birth weight	Distance to road	Name/surname
Toilet type	Number individuals in household	Distance to school	Date of birth
Electricity	Number children in household		Alive/dead
Cooking fuel			Co-residency
Asset index quintile			Marital status
Perceived financial status			Education level
Missing meals frequency			Employment status

*The ACDIS and core datasets contain information on individuals, households, pregnancies, deaths, relationships and residency, this information is gathered from a key informant in each household (i.e. head of household) twice yearly (Tanser et al., 2008).

Information would be listed using the individuals DSID as the criteria for inclusion in the database.

All variables were recoded into appropriate values using STATA to allow a regression analysis to be carried out. All missing values were also allocated a category to ensure all participants were included in the regression analysis.

4.7 Analysis of data collected

STATA 11.0 statistical package was used to analyse all data (StataCorp, 2009). The author (EC) attended a course on the use of this programme and received further training from an Africa Centre statistician.

4.7.1 Descriptive statistics of all data from the present study

Anthropometry

Having converted anthropometric methods (BMI, height, weight and body fat) into the following age-adjusted outputs: BMI-for-age, height-for-age, weight-for-age and body fat-for-age, this information was then displayed as histograms, showing each category by grade and gender. Data were also analysed using ANOVA to determine any significant differences between grade and gender groups. Given that there are no references for MUAC, the results from this technique could not be categorised and were instead displayed as a box plot for each grade and gender, in order to display the range of measurements.

Assessment of agreement between anthropometric methods using weighted kappa analysis

To compare agreement between the different measures for classifying an individual as either underweight, healthy, overweight or obese a weighted kappa analysis was carried out between 4 of the measures, BMI-for-age (both WHO and Cole/IOTF), weight-for-age (CDC) and body fat-for-age (McCarthy) using the Landis and Koch categories (Landis and Koch, 1977) 0 - 0.2 slight agreement, 0.21 – 0.40 fair agreement, 0.41 – 0.60 moderate agreement, 0.61 – 0.80 substantial agreement, 0.81 – 1.00 almost perfect agreement.

Lifestyle data

For each question asked in the lifestyle questionnaire the answers were displayed as histograms by grade and gender; categories were also presented in table format as n (%).

Physical activity data – accelerometry

Results of accelerometry were displayed in a table as median (IQR) for each grade and gender. The measures displayed were total hours worn per day, single counts per minute, integrated counts per minute, % time spent sedentary, % time spent in light intensity activity, % time spent in moderate - vigorous physical activity (MVPA).

Two different references were used for physical activity cut points (Puyau and Evenson) (Trost et al., 2010) and these were compared with each other to assess their differing categorisation of physical activity intensity and therefore achievement of international recommendations.

Accelerometry data for the 7 year olds (grade 1) was also compared to that of a similar age matched sample from England (Gateshead Millenium study) to allow comparison between a western population and a rural African population (Basterfield et al., 2011b). Comparison was possible between these two studies as methods, hardware and cut points used were the same and the sample was also age-matched.

Dietary data - 24 hour multiple pass recall

Results of dietary assessment were displayed in a table as median (IQR) for each grade and gender. The measures displayed were energy (kJ), energy (kcal), energy (kJ/kg/day).

4.7.2 Further analysis investigating relationships of individual and household factors with anthropometric outcomes

Relationship of anthropometric measures (BMI (WHO and Cole/IOTF), body fat, height-for-age and MUAC) with ACDIS variables

Anthropometric references were classified as follows: BMI (WHO and Cole/IOTF) – overweight/not overweight, body fat - overfat/not overfat and height-for-age - stunted/not stunted. Given the lack of reference data, MUAC could not be categorised and so was analysed as a continuous variable. The weight-for-age CDC reference was not used in this analysis, as BMI-for-age is the more commonly used and widely recognised reference and weight-for-age is not ideal for use in older children and adolescents.

- *Descriptives* - A descriptive table of classification was produced displaying n (%) for each reference along with a X^2 or Mann Whitney statistic to determine statistical difference between categories.

- *Univariable and multivariable regression of BMI (WHO and Cole/IOTF), body fat, height-for-age and MUAC in relation to ACDIS variables* -After producing a table of basic descriptives each reference was analysed against each individual ACDIS variable, a logistic regression was used for analysing the categorical variables BMI (WHO, and Cole/IOTF), body fat and height-for-age and a linear regression was used to analyse MUAC since it was a continuous variable. Any variables which had results which reached significance or displayed a noteable trend (increased/decreased risk between different categories) in the univariable analysis were then also placed into a multivariable analysis.

- *Multinomial analysis of BMI (WHO and Cole/IOTF) and body fat in relation to ACDIS variables* -The following anthropometric references, BMI (WHO and Cole/IOTF) and body fat were reclassified as underweight/underfat, healthy and overweight/overfat. A multinomial logistic regression was then carried out on each to assess relative risk of being underweight/underfat or overweight/overfat versus being healthy.

4.7.3 Relationship of anthropometry with lifestyle variables

Univariable and multivariable regression of BMI (WHO and Cole/IOTF), body fat, height-for-age and MUAC in relation to lifestyle data

Using the anthropometric references classified as follows (BMI (WHO and Cole/IOTF) – overweight/not overweight, body fat - overfat/not overfat, height-for-age - stunted/not stunted) and MUAC as a continuous variable, univariable analysis was carried out in a similar fashion as for the ACDIS variables (explained above) and any significant variables were also then placed into a multivariable analysis.

4.7.4 Relationship of anthropometry with physical activity and dietary data

Again the anthropometric references were classified as follows: BMI (WHO and Cole/IOTF) – overweight/not overweight, body fat - overfat/not overfat and height-for-age - stunted/not stunted. Details of each categorised variable, shown by median (interquartile range), were then analysed for significant differences between physical activity and diet-related measures. For example percentage time spent in sedentary, light and moderate - vigorous intensity physical activity was compared between overfat and not overfat individuals to determine whether any significant differences existed between the two groups.

4.7.5 Additional analysis of MUAC to determine potential use as an indicator of overweight and obesity

MUAC is traditionally used to identify undernutrition and as shown in Chapter 6 values have been proposed for guidelines to identify malnutrition. However, no data currently exist on the relationship of MUAC with overweight and obesity and no studies have investigated the possibility that this may be a simple field measure to aid in the diagnosis of overweight and obesity.

Given that this was a reasonably large sample and very few studies have carried out large scale measurement of MUAC it was decided that additional analyses would be carried out on the MUAC data from the present study. This additional analysis aimed to assess the use of MUAC in diagnosing overweight and provide a means of determining what the most appropriate cut off for overweight and overfatness might be at different age groups.

After discussion with a statistician at the Africa Centre it was decided that a Receiver operating characteristic (ROC) curve analysis was the most appropriate method to use.

This analysis involved three stages: developing ROC curves, developing probability curves and then making a final decision of appropriate cut points based on sensitivity and specificity. This process is explained below.

To examine the possible association between MUAC measurement and categorisation as overweight or overfat a ROC curve analysis was performed comparing MUAC to body fat data and also MUAC to WHO BMI-for-age data.

Current guidelines are based on young people aged 5 - 9 years and aged 10 - 14 years for this reason I divided the present sample into these age-specific groups and further categorised by sex.

MUAC data was then plotted against:

i. body fatness using the McCarthy 2006 body fat reference where any individual defined as overfat or obese was coded as 1 and all others as 0.

ii. weight status using the WHO 2007 BMI-for-age reference where any individual defined as overweight or obese was coded as 1 and all others as 0.

ROC curves were created for each age- and sex-specific group and by both body fatness and weight status using STATA command roctab. This gives a ROC curve which shows the specificity and sensitivity of the measure. In order to allow determination of the optimal operating point (OOP) it was then necessary to create a probability curve based on a logit equation which was calculated separately for each age- and gender-specific group. This equation was performed in STATA and the probability of overweight or overfatness was then computed for each individual MUAC measure dependent on the category it was in. Results of this analysis are shown in Chapter 6 : MUAC.

4.7.6 Mapping of geographical distribution of study participants and distribution of overweight, overfat and stunting.

Every individual who had been matched to their BSID was shown on a map of the whole DSA to give an idea of the geographical distribution of participants in the study. This map could then be compared to another map showing the total population density of the area to visually show why some areas were more densely sampled, i.e., highly populated urban areas and others which were more sparsely populated, i.e., rural areas.

In addition to this general map, an individual map was then made for each of the anthropometric references (BMI WHO, BMI Cole/IOTF, weight-for-age, body fat, and height-for-age) to show the geographical distribution of overweight vs. not overweight, overfat vs. not overfat and stunted vs. not stunted respectively, and to allow observation as to whether there was clustering within specific areas or whether the results were random across the sample.

Results of the present study are presented in Chapters 5 - 8 of this thesis.

5 Prevalence of overweight and obesity in rural South African children and adolescents. (additional data on stunting prevalence)

This chapter describes the results of the cross-sectional study which aimed to assess the prevalence of overweight and obesity in children and adolescents in this rural South African population and also presents results on height-for-age

The chapter is divided into four sections:

Section 1 - Describes recruitment, consent rates and representativeness of the sample.

Section 2 - Briefly describes the anthropometric measures and references used in the study (explained in detail in Chapter 3: Justification of methods).

Section 3 – Overnutrition. Presents prevalence data on overweight and obesity and includes presentation of data using BMI-for-age (WHO 2007), BMI-for-age (Cole/IOTF 2000 and Cole 2007 referred to collectively as Cole/IOTF, weight-for-age (CDC 1977) and body fat (McCarthy 2006). When specifically using the body fat reference the terms overfat and obese are used rather than overweight and obese. There are four sub-sections:

i. descriptive figures for each measure

ii. a map for each reference which shows the geographical distribution of the overweight/overfat status of individuals by each anthropometric method

iii. prevalence n (%) of underweight, healthy weight, overweight/overfat and obese for each reference

iv. results of a weighted kappa analysis showing agreement between the anthropometric measures

Although the aim of this thesis is primarily focussed on presenting results of overweight and obesity prevalence in children and adolescents, the area in which this work took place is currently undergoing nutrition transition and undernutrition remains a substantial problem. For this reason data are also presented on stunting and; data most commonly used to classify undernutrition. Stunting is generally used to diagnose long term chronic undernutrition. Measurement of this would allow us to determine the current prevalence of chronic undernutrition in this sample as well as to investigate the relationship between height-for-age and overweight status. Stunting has been highlighted as a possible risk factor for predisposition to overweight and obesity in later life (Dewey and Begum, 2011, Cameron et al., 2005b) and therefore this relationship would also be considered.

Section 4 – Stunting. This section provides the results of the height-for-age data showing descriptive tables and the geographical distribution of stunting across the study sample.

5.1 Recruitment, consent and representativeness of sample

5.1.1 Overall recruitment by grade and gender

Table 5-1 shows the final recruitment rates for the full sample in the cross-sectional study, shown as total numbers and also by grade and gender. The target of at least 500 individuals to be recruited from each chosen grade was achieved, with a total sample size of 1,519 individuals. A similar percentage of boys and girls, approx 50% from each gender, was recruited in school grades 1 and 5, however, there was a higher percentage of girls (63.7%) than boys (36.3%) recruited in school grade 9, possibly due to the increased interest girls tend to have in weight status and body image at this age.

Table 5-1 Final recruitment of study sample by grade and gender

School Grade (mean age)	*Total n*	*Boys n (%)*	*Girls n (%)*
1 (7 years)	514	264 (51.4)	250 (48.6)
5 (11 years)	503	234 (46.5)	269 (53.5)
9 (15 years)	502	182 (36.3)	320 (63.7)
	1519	**680**	**839**

5.1.2 Consent rates

The consent rate for each grade was calculated as the number of consent forms given out and the number of individuals returning a signed form and thus being eligible to participate in the study.

Rates were as follows:

- School grade 1 – Badly affected by national strikes (explained below). Those schools not affected, i.e., where children had been measured before the strikes began, had consent rates ranging from 41-55%.

- School grade 5 – Range: 54 - 96% Mean: 75%

- School grade 9 – Range: 50 - 60% Mean: 56%

Overall consent rate was approximately 70%.

School strikes

South Africa suffered a three week long public sector strike from 10 August - 7 September 2010. This strike affected workers throughout the public sector including hospitals, schools and many government officials (Barbee, 2010). In total, 6,000 schools were closed during this strike period and many school exams were cancelled as a result. The reason for the strike was a rejection by the government to meet the 8.6% wage increase demanded by public sector unions. Despite the government offering a 7.5% increase unions refused and made the decision to fight for the remaining 1.1% (Cohen, 2010). The results of the strike were catastrophic and included many cases of extreme violence: rubber bullets and water cannons were used by the police in an attempt to control protesters, buildings were vandalized, items were set on fire and the reduced provision of medical care in hospitals resulted in many individuals dying unnecessarily (Barbee, 2010). The final conclusion of the strike was that it was suspended with no definitive outcome achieved.

This national strike took place over the data collection period assigned for the grade 1 pupils, thus caused some scheduling problems and resulting in lower consent rates from this group, given the high levels of disruption to schooling. Schools themselves were also possibly less keen to take part, given the large amount of learning time learners had already missed out on (See Appendix 24 for local media coverage of the strike).

Representativeness of the sample and distribution of individuals in the sub-district

Representativeness of the study sample in relation to the overall DSA population was examined using two indicators of socio-economic status, the presence of piped water in the home and the availability or otherwise of a connection to the electricity grid. Study participants were asked for their DSA household identification number at the time of enrolment. Using this identification number and other unique identifying data (including name, date of birth and parents' names) around 70% of the enrolled study sample in each grade was matched to their household data from the DSA; the remaining 30% was unmatched due to a lack of identifying data being provided by participants and/or their parents. These indicators are presented in Table 5-2 for both the study sample and the DSA population, using information from the Africa Centre Household Surveillance (Colin Newell, personal communication, September 2011) to display the extent to which the sample for the present study matched the general population, as described by DSA data. Only one variable in one age group (availability of electricity at home amongst 7 year olds) was found to be significantly different between the present study and the total DSA population, suggesting the present sample was broadly socio-economically representative of the wider DSA.

The population resident within the DSA is essentially Zulu (governed predominantly by the Zulu land ownership system where the king controls who can build houses); therefore there was no need to account for differences in ethnicity between participants.

Figure 5-1 shows the overall population density within the DSA and Figure 5-2 shows the distribution of the matched sample across the DSA. All maps in this chapter are on the same scale, shown in Figure 5-1, as 1:57,470. The colour coding on the map denotes different isigodi (tribal regions), the orange area in the most southern part of the map depicts the only township within the DSA, KwaMsane, hence the increased population density in this area.

Table 5-2 Representativeness of present sample compared to 2010 data from the same-aged population of the demographic surveillance area (DSA)

	Age 7			Age 11			Age 15		
	Full DSA	**Present Study (% of DSA)**	**P**	**Full DSA**	**Present Study (% of DSA)**	**P**	**Full DSA**	**Present Study (% of DSA)**	**P**
Total (n)	1665	343[a](20.6)		1742	377[b](21.6)		1864	357[c](19.2)	
Electric at home (%)	58.6	69.1	0.003*	57.5	60.5	0.41	59.0	63.6	0.20
Access to Piped Water (%)	56.2	60.1	0.31	55.5	57.8	0.52	56.4	63.3	0.06

***significant difference between DSA and present study**

[a] 343 matched to BSID out of 514 = 66.7%

[b] 377 matched to BSID out of 503 = 75.0 %

[c] 357 matched to BSID out of 502 = 71.1%

BSID = Bounded Structure Identifier

Bounded Structures are physical units that can be directly observed in the field (even in the absence of an informant). They are either a single building, or a clustered group of buildings, owned by a single owner and located on an identifiable plot of land (e.g., a designated stand in urban areas, or a fenced estate in rural areas). They can be represented by a point in a Geographical Information System. Most Bounded Structures are Homesteads, i.e., residential, but others can be schools, clinics, shops, churches etc.

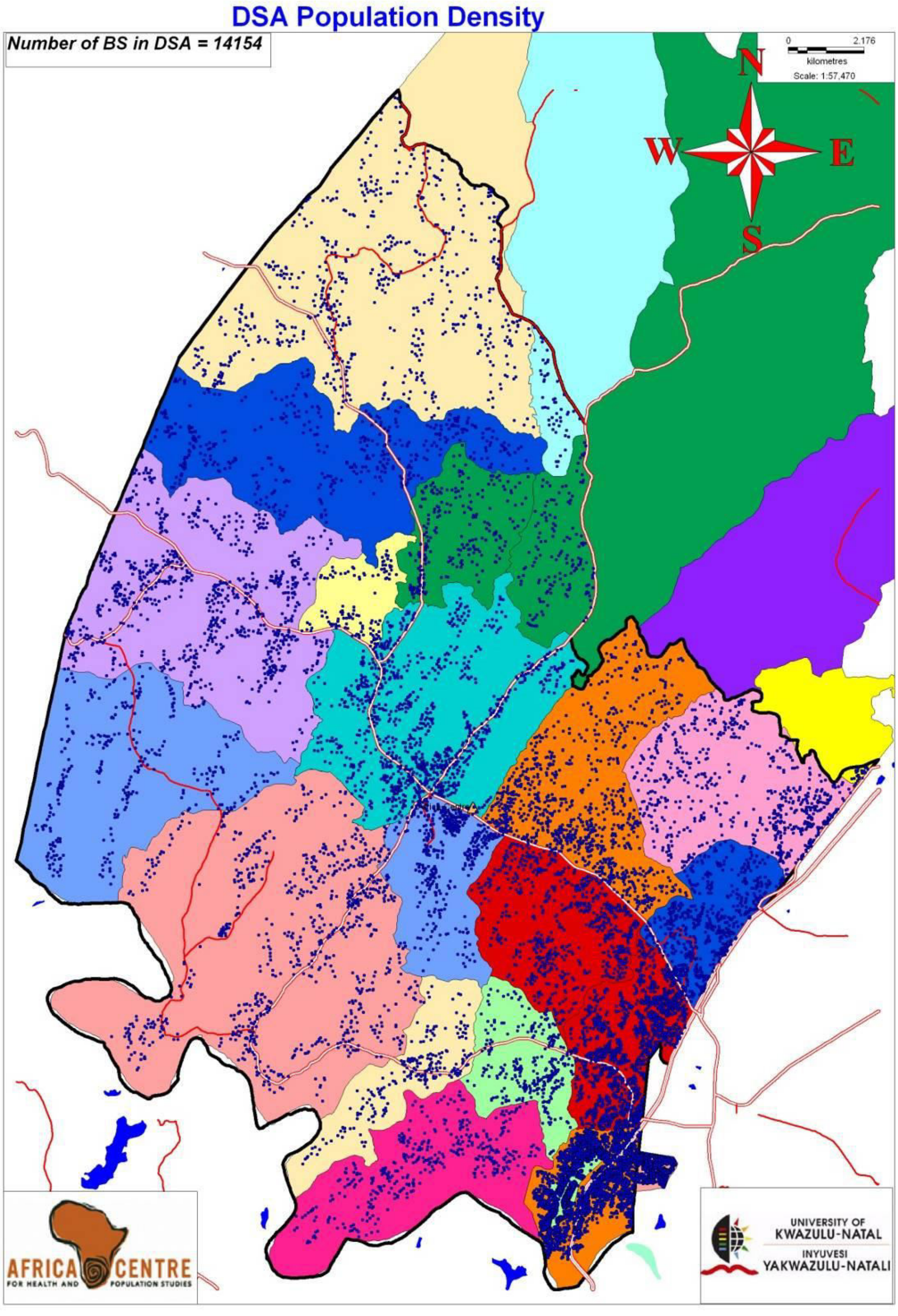

Figure 5-1 Overall Population Density within the demographic surveillance area (DSA)
BS = Bounded Structure

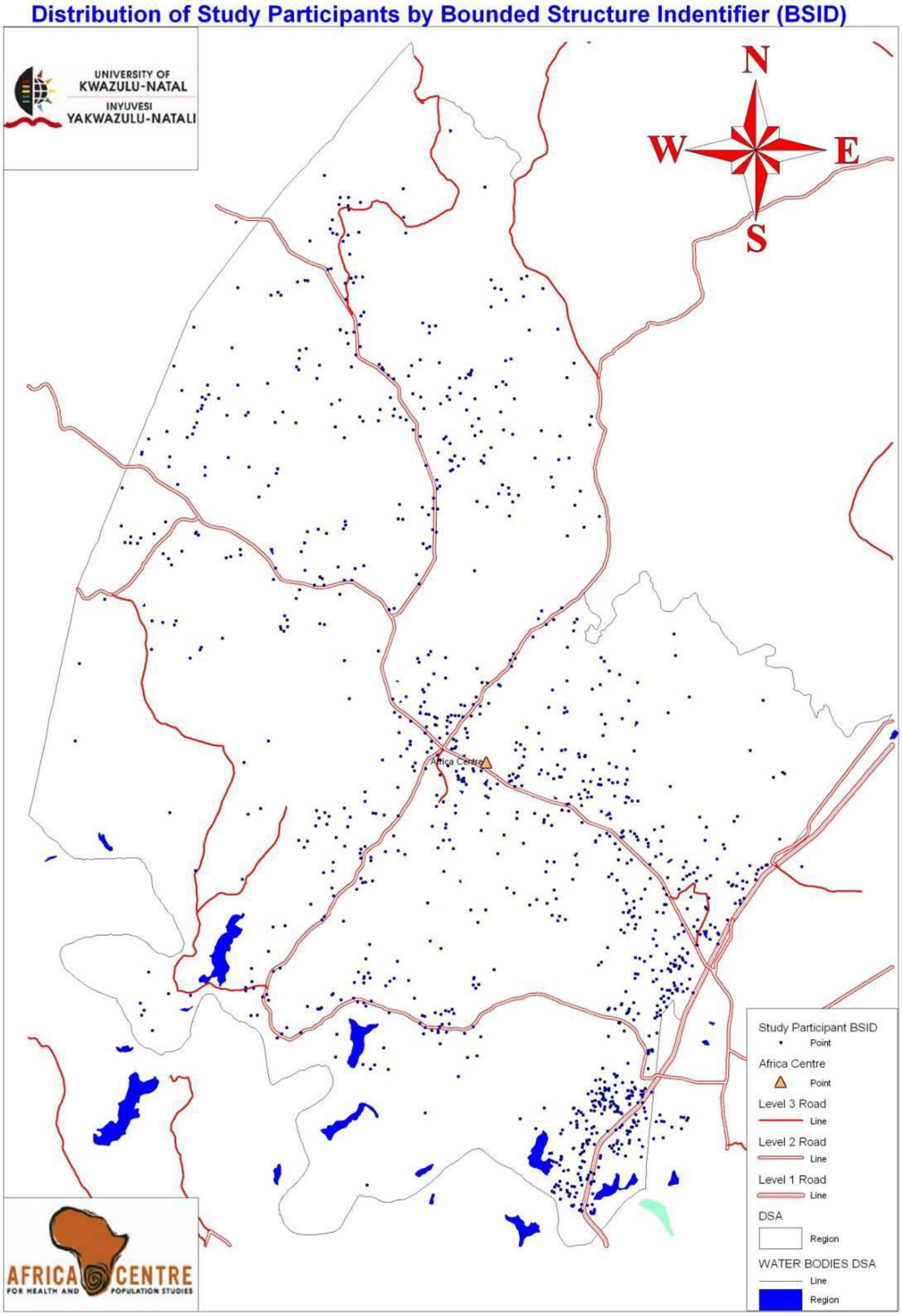

Figure 5-2 Distribution across Demographic Surveillance Area (DSA) of participants within present study (Scale 1 : 57,470)

5.2 Anthropometric measures used in the cross-sectional study

As described previously in Chapters 3 and 4, the anthropometric measures used were height, weight, body fat and mid-upper arm circumference which allowed calculation of the following outputs using the appropriate references:

- Weight status using BMI (height/weight2 kg/m2) / BMI-for-age z-score (WHO 2007 and Cole/IOTF 2000)
- Body fatness using body fat-for-age categories (McCarthy 2006)
- Weight status using weight-for-age z-score (CDC 1977)
- Stunting using height-for-age z-score (WHO 2007)
- Nutritional status using mid-upper arm circumference measurements (see Chapter 6 for results)

5.2.1 Anthropometric characteristics of study participants

Table 5-3 shows the anthropometric characteristics of study participants as median (IQR), by each grade as a whole and then each grade by gender. Median BMI z-score, using the WHO 2007 reference, was negative (i.e. z-score <0) at all time points except for girls in grade 9. Body fat percentage in boys was lower in the middle than in the youngest age group and lower still in the oldest age group, however, in girls the opposite was the case, with the highest level in the oldest age group. Median height-for-age z-score was negative in both sexes and at all three age groups.

It was estimated this study would have a power of at least 80% however the final results suggest the power of this study was infact considerably higher than this (95%).

Table 5-3 Anthropometric and body composition characteristics of study participants, median (IQR).

Median (IQR)	School Grade 1 Age 7 years			School Grade 5 Age 11 years			School Grade 9 Age 15 years		
	All	Boys	Girls	All	Boys	Girls	All	Boys	Girls
Total (N)	514	264	250	503	234	269	502	182	320
Age (years)	6.9 (6.8 –7.8)	6.9 (6.8 – 7.9)	6.9 (6.8 –7.8)	11.2 (10.6 – 12.3)	11.6 (10.9 – 12.7)	10.9 (10.4 -11.8)	15.2 (14.5 – 16.3)	15.6 (14.8 – 16.8)	15.1 (14.5 – 16.0)
Height (cm)	118.7 (114.3 – 122.8)	118.7 (114.5 – 123.3)	118.6 (114.1 – 122.4)	141.3 (136.7-146.9)	141.5 (136.7-146.9)	141.1 (136.6 – 146.9)	159.5 (154.1 - 165.7)	166.4 (159.2-170.8)	157.0 (152.7 – 162.1)
Weight (kg)	21.6 (19.5 – 23.8)	21.8 (19.6 – 23.7)	21.3 (19.3 – 23.9)	33.7 (30.4 – 39.5)	33.6 (30.6 – 38.8)	34.0 (30.4 – 40.1)	52.6 (46.9 – 59.4)	52.7 (47.6 – 60.2)	52.5 (46.2 – 58.6)
BMI ($kg.m_2$)	15.3 (14.5 – 16.3)	15.3 (14.6 – 16.1)	15.3 (14.4 – 16.7)	16.9 (15.7 -18.4)	16.8 (15.7 – 17.9)	17 (15.9 – 19.1)	20.1 (18.6 – 22.5)	19.5 (18.0 – 21.0)	20.9 (19.0 – 23.6)
BMI- for-age z-score (WHO)[a]	-0.18 (-0.77 – 0.46)	-0.23 (-0.78 – 0.38)	-0.15 (-0.76 – 0.59)	-0.25 (-0.91 – 0.41)	-0.42 (-0.99 – 0.16)	-0.1 (-0.76 – 0.63)	-0.03 (-0.68 – 0.73)	-0.28 (-1.06 – -0.28)	0.31 (-0.50 – 1.02)
Height-for-age z-score (WHO)[b]	-0.86 (-1.61 – -0.07)	-0.88 (-1.66 – -0.11)	-0.78 (-1.51 – 0.06)	-0.68 (-1.43 – -0.01)	-0.99 (-1.6 – -0.23)	-0.51 (-1.26 -0.11)	-0.66 (-1.31 – 0.06)	-0.76 (-1.51 – -0.03)	-0.58 (-1.25 – 0.08)
Body Fat (%)[c]	17.7 (15.4 - 20.7)	16.8 (15.0 – 18.9)	19.5 (16.1 – 22.2)	15.8 (12.3 – 21.3)	12.3 (10.1 - 14.6)	20.3 (16.7 – 24.2)	20.1 (10.6 – 26.6)	9 .0 (6.5 – 11.8)	24.7 (20.1 – 29.5)

[a,b] WHO 2007 (WHO, 2007) [c] McCarthy 2006 (McCarthy et al., 2006)

5.3 Prevalence of overweight/overfat and obesity status using 4 methods: BMI-for-age (WHO), BMI-for-age (Cole/IOTF), body fat (McCarthy) and weight-for-age (CDC)

The descriptive graphs showing the distribution of z-scores for each reference by grade and gender are shown below and Table 5-4 displays descriptive statistics of the anthropometric measures, indicating where there was a significant difference between school grades and gender groups, analysed using ANOVA as stated on page 120.

5.3.1 Descriptive graphs and tables for study participants' anthropometric status

Weight status (WHO 2007– BMI-for-age)

Data appear normally distributed with approximately 95% of both males and females falling within the 'normal' range (between -2 and +2 z-scores), however, when looking at the overweight category (>+2 SD) it can be seen that grade 9 females have a higher prevalence (8.0%) of overweight and obesity than all other age groups both male and female. Compared to females, more males were classified as underweight (<-2 SD): less than 2% in all female age groups versus 3.4%, 5.2% and 6.2% in grade 1, 5 and 9 males respectively (see Figure 5-3 and 5-4).

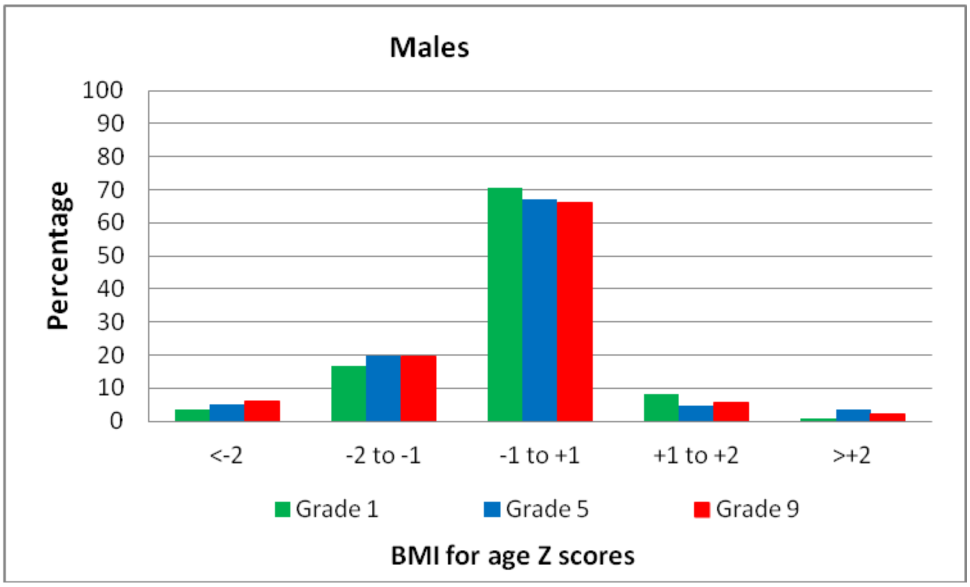

Figure 5-3 Weight status of male study participants (WHO BMI-for-age)

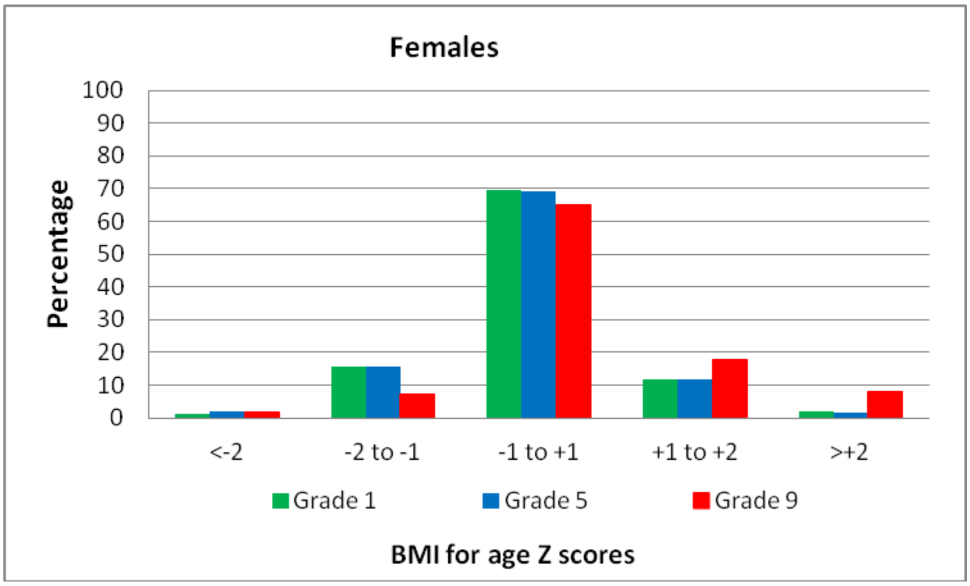

Figure 5-4 Weight status of female study participants (WHO BMI-for-age)

Weight Status (Cole/IOTF BMI-for-age)

As for WHO BMI-for age, the Cole/IOTF reference also shows that females in grade 9 display the highest level of overweight and obesity. Combined overweight and obesity was 23% in grade 9 girls compared to only 6% in boys of the same age. Similar to the WHO reference the grade 9 males had a higher prevalence of underweight than the females, 15.8% and 8.2% respectively, although there was little difference between males and females in grade 1 (16.0 and 15.1% respectively) and grade 5 (12.9% and 12.3% respectively) (see Figure 5-5 and 5-6).

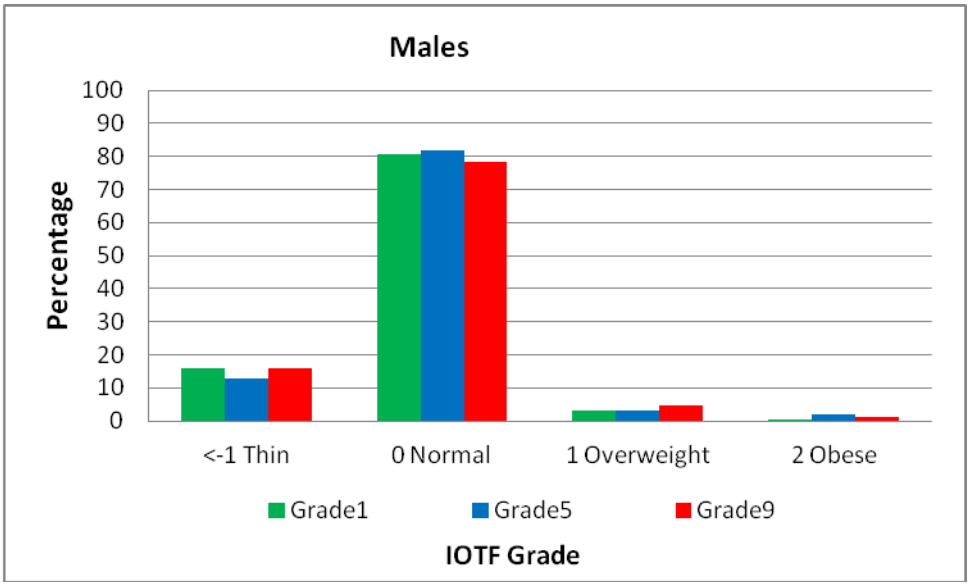

Figure 5-5 Weight status of male study participants (Cole/IOTF BMI-for-age)

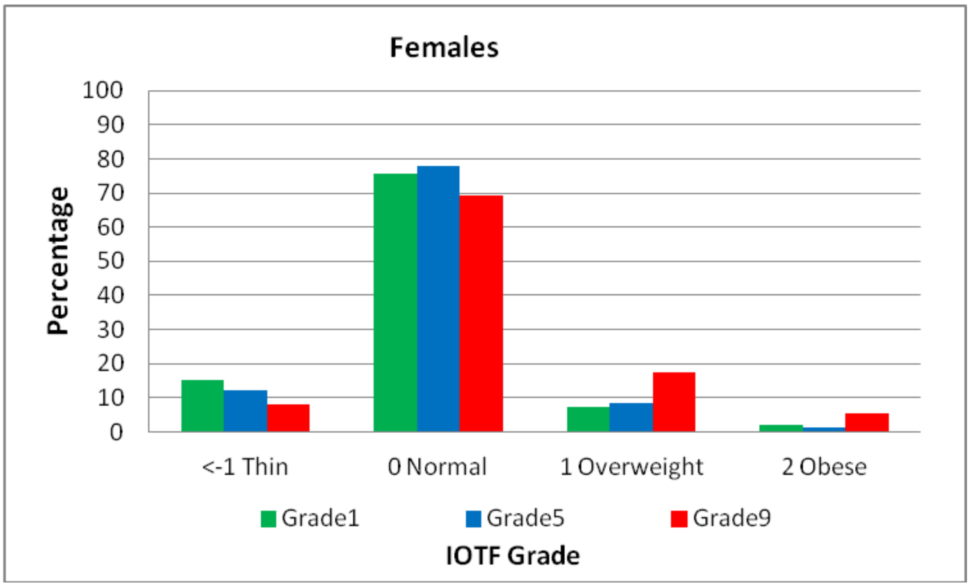

Figure 5-6 Weight status of female study participants (Cole/IOTF BMI-for-age)

Weight status (CDC 1977 weight-for-age)

The majority of individuals were within the ‘normal’ weight-for-age z-score range (between -2 and +2). The distribution was similar for both males and females (see Figure 5-7 and 5-8).

Figure 5-7 Weight status of male study participants (CDC Weight-for-age)

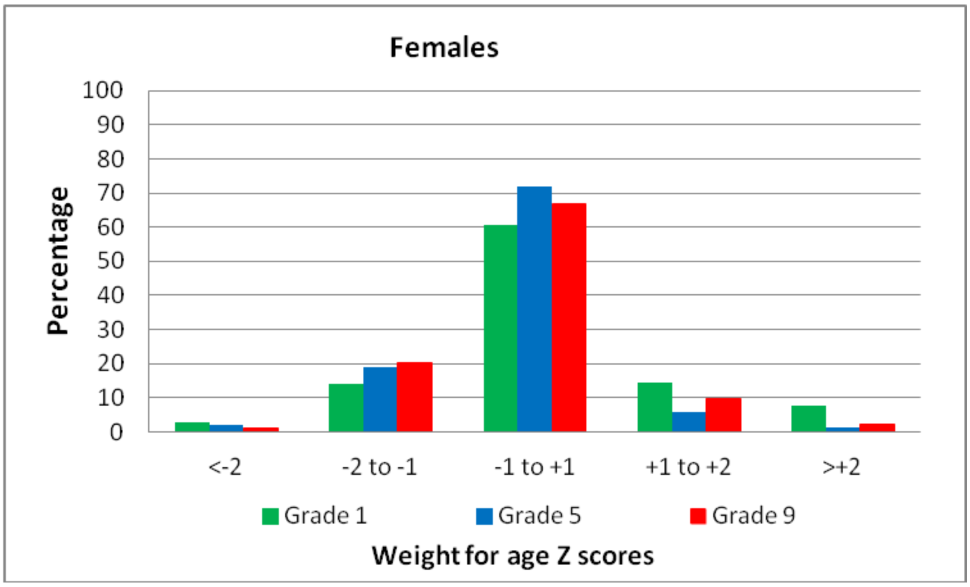

Figure 5-8 Weight status of female study participants (CDC Weight-for-age)

Body fatness (McCarthy 2006 - body fat-for-age)

The proportion of males classified as healthy (i.e. non overweight, non obese) varied greatly between the grades with 74.4% classified as healthy in grade 1 but only 45.7% and 35.9% as healthy in grade 5 and 9 respectively; less difference existed for females with those categorised as healthy being 63.1%, 71.7% and 67.6% in grades 1, 5 and 9 respectively.

The most striking difference between males and females overfat status is in grade 9. The combined figure of overfat and obese for grade 9 boys was approximately 5%, whereas for grade 9 girls this was 23%. Grade 1 also shows high levels for both males and females, although the likely cause of this is not so apparent. A high percentage of grade 9 boys (60%) were classed as underfat (see Figure 5-9 and 5-10).

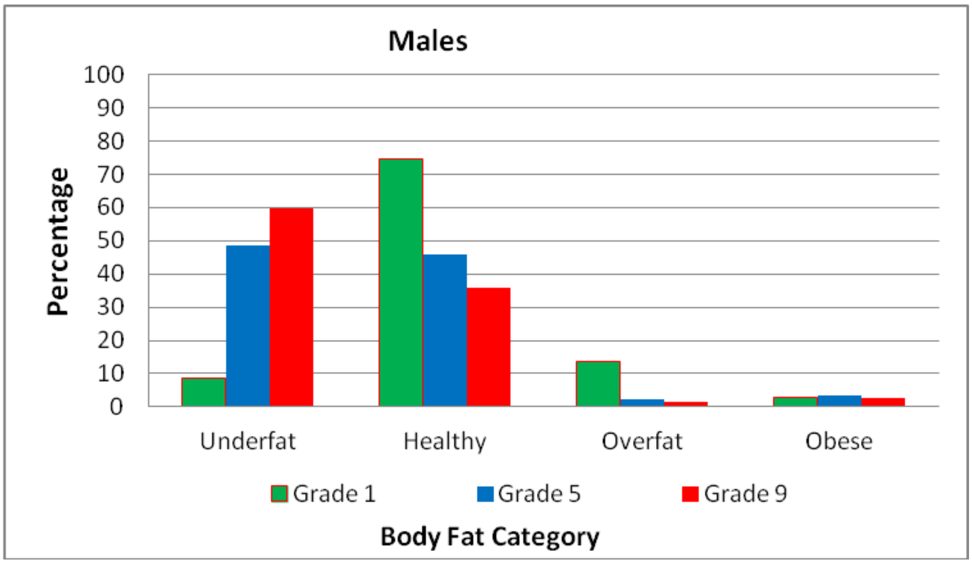

Figure 5-9 Body fatness of male study participants (McCarthy 2006)

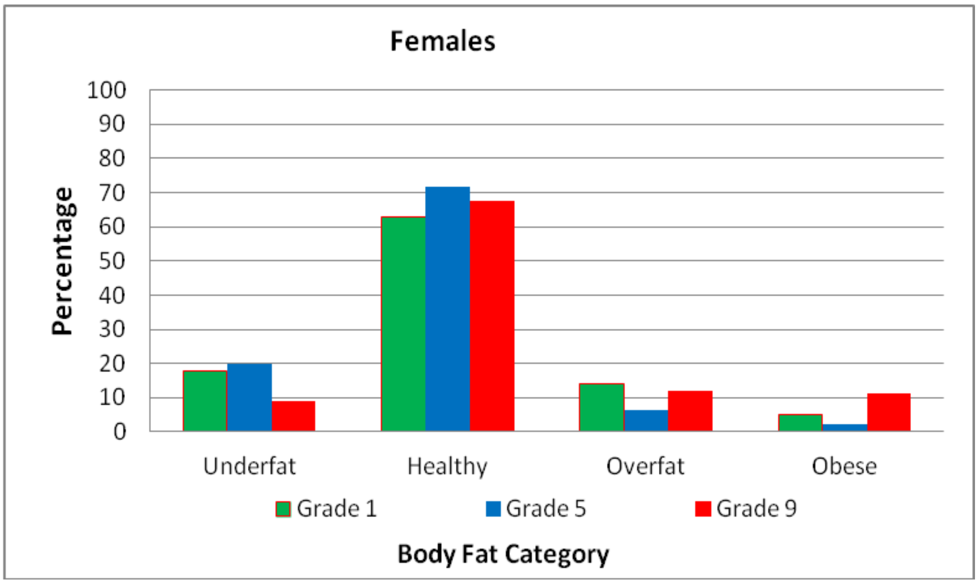

Figure 5-10 Body fatness of female study participants (McCarthy 2006)

Table 5-4 Descriptive statistics of anthropometric measurements, analysed by school grade and gender

Mean (SD)	**Boys**			**Difference between grades**	**Girls**			**Difference between grades**	**Difference between sexes**
School Grade	**1**	**5**	**9**	**p**	**1**	**5**	**9**	**p**	**p**
BMI-for-age Z score (WHO)	-0.24 (0.06)	-0.36 (0.07)	-0.37 (0.09)	0.29	-0.07 (0.06)	-0.08 (0.06)	0.26 (0.07)	<0.01*	**G1** 0.05 **G5** 0.02 **G9** <0.01
Weight-for-age Z score	-0.20 (0.07)	-0.66 (0.06)	-0.56 (0.08)	<0.01ɫ	0.20 (0.08)	-0.29 (0.05)	-0.09 (0.06)	<0.01ɫ	**G1** <0.01 **G5** <0.01 **G9** <0.01
Height-for-age Z score	-0.90 (0.07)	-0.91 (0.07)	-0.66 (0.12)	0.09	-0.77 (0.07)	-0.54 (0.06)	-0.52 (0.07)	0.02ɫ	**G1** 0.21 **G5** <0.01 **G9** 0.29

G1= School Grade 1, G5 = School Grade 5, G9=School Grade 9
*School grade 9 significantly different (p<0.05) to school grades 1 and 5
ɫ School grade 5 and 9 significantly different (p<0.05) to school grade 1

5.3.2 Demographic Surveillance Area (DSA) distribution maps

Of the full cross-sectional sample, (1,320/1,519) 86.9% were matched to their household via the Africa Centre Demographic Information System (ACDIS) database (discussed previously in Chapter 4: Methods) and the following figures (Figure 5-11, 5-12, 5-13, 5-14) show the geographical distribution of those found to be overweight or overfat by the 4 different references.

The area to the south east of the demographic surveillance is the region where the only township in the sub-district is located, this explains the reasons for an increased clustering of numbers from this area. It can also be seen that there are a slightly higher number of children diagnosed as overweight or overfat in this region when compared to more rural locations within the DSA.

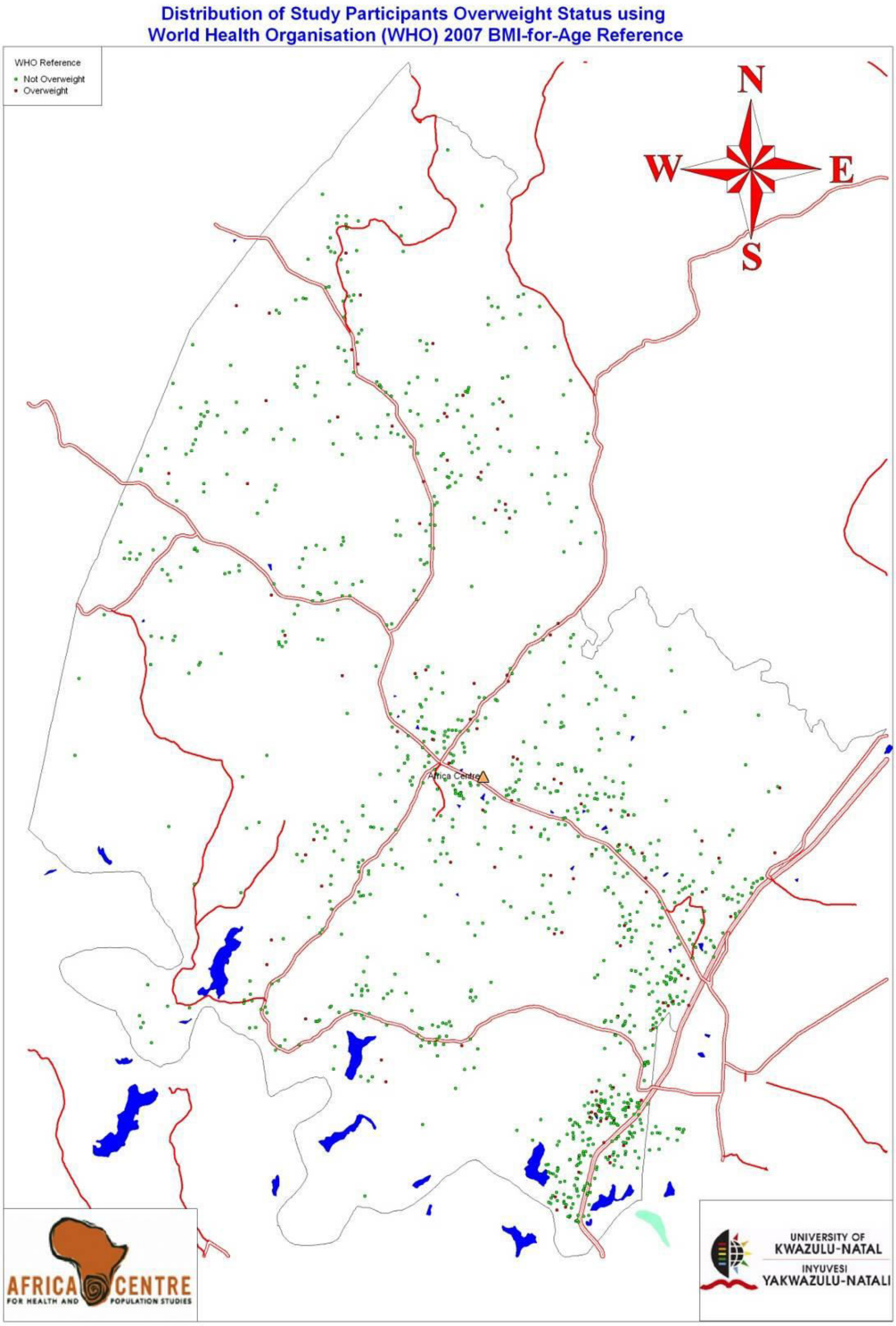

Figure 5-11 Weight status of participants by geographical distribution (WHO 2007 BMI-for-age) (Scale 1 : 57,470)

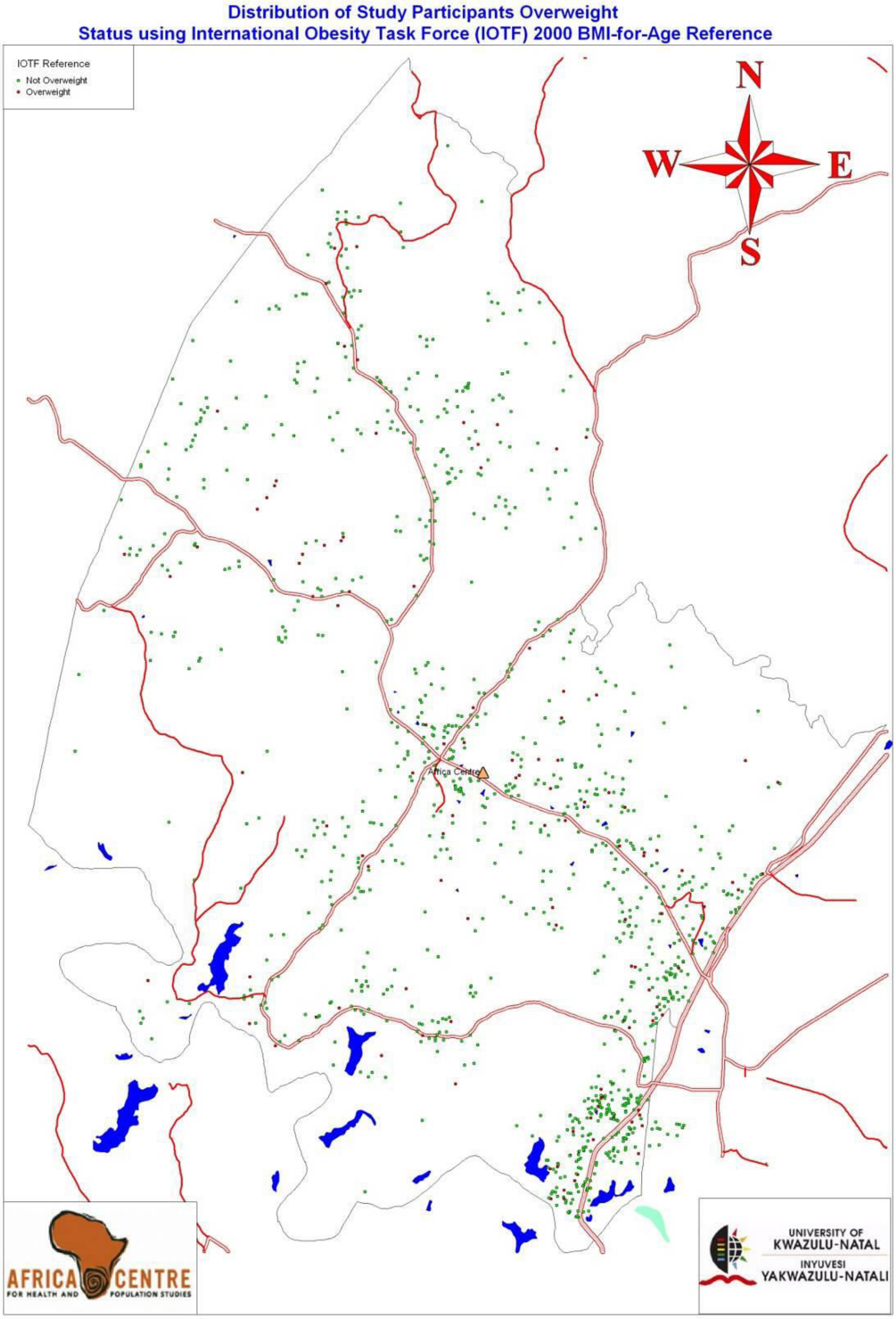

Figure 5-12 Weight status of participants by geographical distribution (Cole/IOTF 2000 BMI-for-age) (Scale 1 : 57,470)

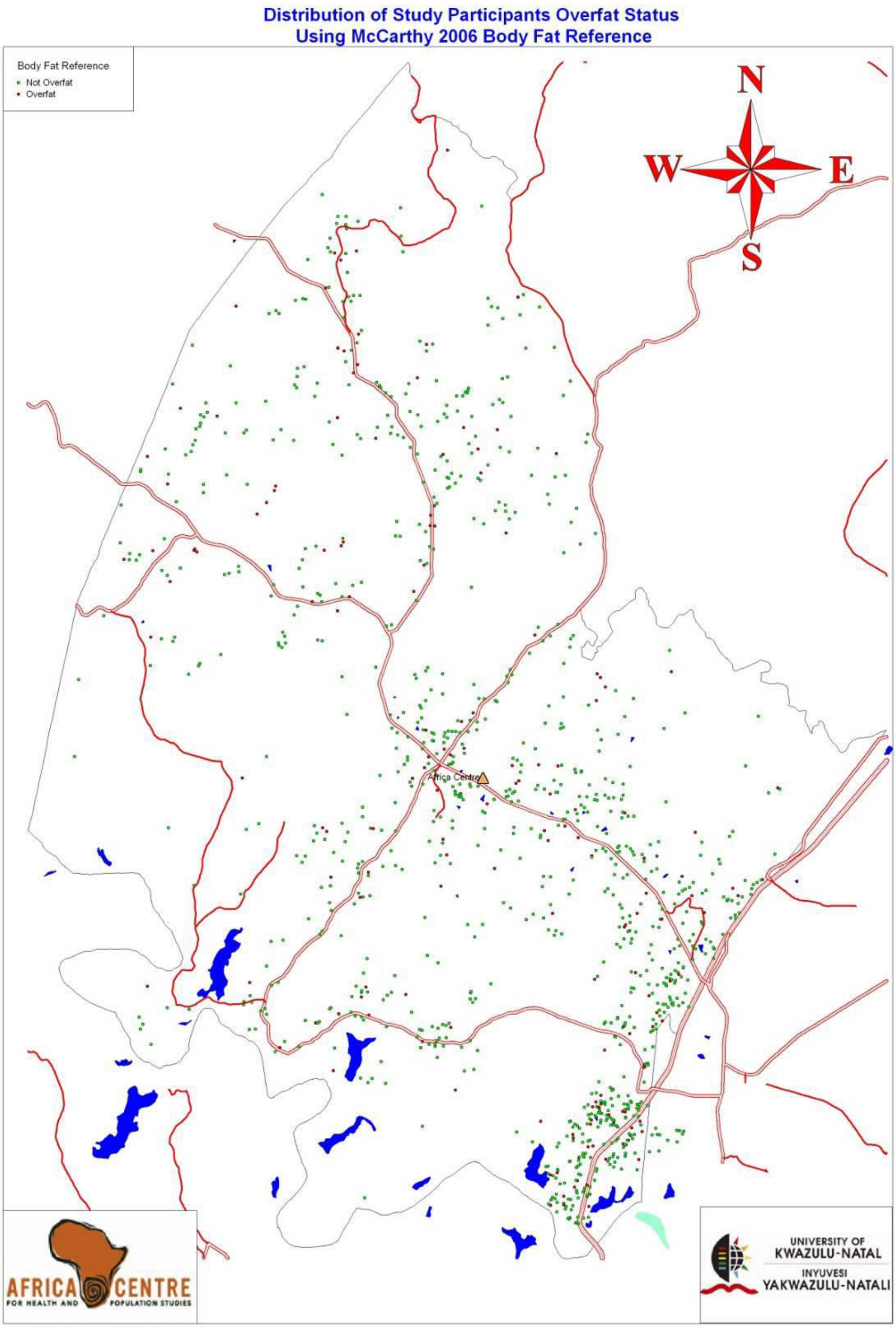

Figure 5-13 Body fatness of participants by geographical distribution (McCarthy 2006 body fat-for-age) (Scale 1 : 57,470)

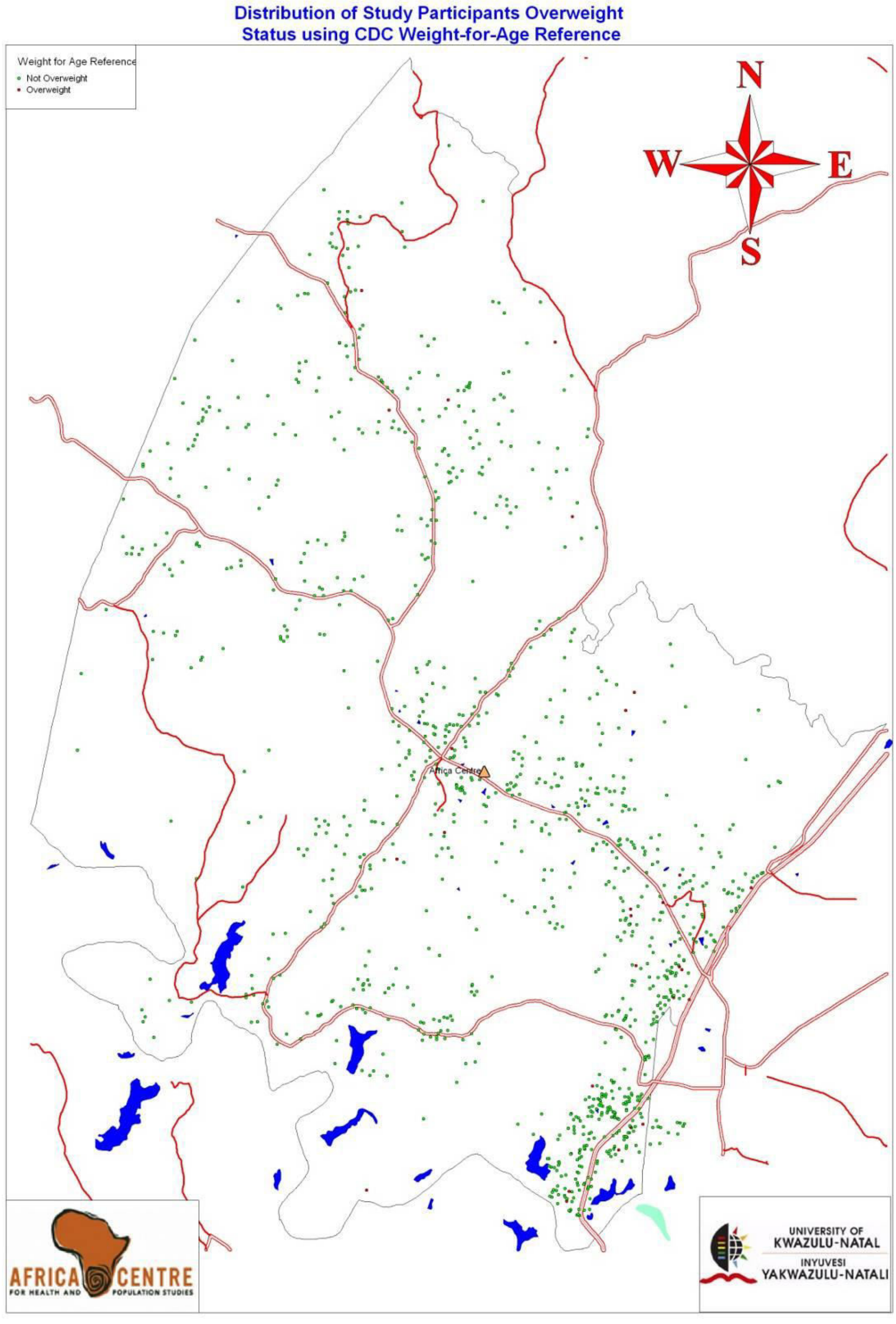

Figure 5-14 Weight status of participants by geographical distribution (CDC 1977 weight-for-age) (Scale 1 : 57,470)

5.3.3 Differences in the prevalence of underweight, overweight and obesity using different anthropometric measures in boys (body fat, BMI-for-age, weight-for-age)

Prevalence of healthy and unhealthy weight status by method and age group in boys is summarised in Table 5-5. The body fat method produced the lowest estimates of healthy weight status in all age groups when compared to BMI-for-age and weight-for-age methods. Discrepancies between weight status assessments based on weight and BMI were strikingly different from those obtained by body fatness measures (Table 5-5): prevalence of healthy weight status in boys by impedance was 74%, 45% and 36% in grades 1, 5 and 9 respectively, versus ranges of 81-88% using CDC, 78-81% using Cole/IOTF, 86-87% using WHO definitions.

Table 5-5 Prevalence of different categories of weight status of boys n (%) [95%CI] using four categories underweight, healthy, overweight and obesity and four international references.

School Grade	Underweight or 'Thin'[a]	Healthy[b]	Overweight or 'Overfat'[c]	'Obese'[d]
(WHO) BMI-for-age (de Onis et al., 2007)				
1	9 (3.4) [1.8-6.4]	230 (87.5) [82.9-90.9]	22 (8.4) [5.6-12.3]	2 (0.8) [0.2-2.7]
5	12 (5.2) [3.0–8.8]	202(86.7) [81.7-90.5]	11(4.7) [2.7-8.3]	8 (3.4) [1.8-6.6]
9	11(6.2) [3.5–10.8]	152 (85.9) [80.0-90.3]	10 (5.7) [3.1-10.1]	4 (2.3) [0.9-5.7]
(Cole-IOTF) BMI-for-age (Cole et al., 2000, Cole et al., 2007)				
1	42 (16.0) [12.0-20.9]	212 (80.6) [75.4-84.9]	8 (3.0) [1.6–5.9]	1 (0.4) [0.1–2.1]
5	30 (12.9) [9.2-17.8]	191 (82.0) [76.5-86.4]	7 (3.0) [1.5-6.1]	5 (2.2) [0.9–4.9]
9	26 (15.8) [11.0-22.1]	129 (78.2) [71.3-83.8]	8 (4.9) [2.5-9.3]	2 (1.2) [0.3–4.3]
(CDC) Weight-for-age (WHO, 1986)				
1	16 (6.2) [3.8-9.8]	211 (81.2) [76.0-85.4]	25 (9.6) [6.6-13.8]	8 (3.1) [1.6-6.0]
5	9 (3.9) [2.1-7.2]	213 (91.8) [87.6-94.7]	8 (3.5) [1.8-6.7]	2 (0.9) [0.2-3.1]
9	12 (7.6) [4.4-12.8]	138 (87.3) [81.3-91.7]	7 (4.4) [2.2-8.9]	1 (0.6) [0.1-3.5]
(McCarthy) Body fat % (McCarthy et al., 2006)				
1	23 (8.8) [5.9-12.8]	195 (74.4) [68.8-79.3]	36 (13.7) [10.1-18.4]	8 (3.1) [1.6-5.9]
5	114 (48.7) [42.4-55.1]	107 (45.7) [39.5-52.1]	5 (2.1) [0.9-4.9]	8 (3.4) [1.7-6.6]
9	110 (60.4) [53.2-67.3]	66 (36.3) [29.6-43.5]	1 (0.6) [0.1-3.1]	5 (2.8) [1.2-6.3]

[a] WHO = z-score of <-2SD IOTF = equivalent to BMI at age 18 of <18.5 CDC = z-score <-2 Body Fat = ranging from 0-12% depending on age
[b] WHO = z-score of ≥-2 and ≤+1SD IOTF = equivalent to BMI at age 18 of ≥18.5 and <25 CDC= ≥-2 and ≤+1 Body Fat = ranging from 10-23% depending on age
[c] WHO = z-score of >+1SD IOTF = equivalent to BMI at age 18 of ≥25 and ≤30 CDC= z-score >+1 to ≤+2 Body Fat = ranging from 20-28%, depending on age
[d] WHO = z-score of >+2SD IOTF = equivalent to BMI at age 18 of >30 CDC= z-score >+2 Body Fat = ranging from 24+% depending on age

5.3.4 Differences in the prevalence of underweight, overweight and obesity using different anthropometric measures in girls (body fat, BMI-for-age, weight-for-age)

Prevalence of healthy and unhealthy weight status by method and age group is summarised in Table 5-6. The highest prevalence of underweight and lowest prevalence of healthy weight status was found using the body fat assessment for all three age groups in girls. Discrepancies between prevalence of unhealthy weight status obtained by body fat assessment versus body weight and BMI based approaches varied with age, but were generally smaller in girls than boys.

Table 5-6 Prevalence of weight status of girls n (%) [95%CI] using four categories: underweight, healthy, overweight and obesity and four international references.

School Grade	Underweight, Underfat or 'Thin'[a]	Healthy[b]	Overweight or 'Overfat'[c]	'Obese'[d]
(WHO) BMI-for-age (de Onis et al., 2007)				
1	3 (1.2) [0.4-3.5]	214 (85.3) [80.3-89.1]	29 (11.6) [8.2-16.1]	5 (2.0) [0.8-4.6]
5	5 (1.9) [0.8-4.3]	228 (84.8) [80.0-88.6]	32 (11.9) [8.6-16.3]	4 (1.5) [0.6-3.8]
9	6 (1.9) [0.9-4.1]	227 (72.3) [67.1-77.0]	56 (17.8) [14.0 -22.5]	25 (8.0) [5.5-11.5]
(Cole-IOTF) BMI-for-age (Cole et al., 2000, Cole et al., 2007)				
1	38 (15.1) [11.2-20.1]	190 (75.7) [70.0-80.6]	18 (7.2) [4.6-11.1]	5 (2.0) [0.9-4.6]
5	33 (12.3) [8.9-16.7]	210 (78.1) [72.8-82.6]	23 (8.6) [5.8-12.5]	3 (1.1) [0.4-3.2]
9	25 (8.2) [5.6-11.8]	211 (69.2) [63.8-74.1]	53 (17.4) [13.5-22.0]	16 (5.3) [3.3-8.4]
(CDC) Weight-for-age (WHO, 1986)				
1	7 (2.8) [1.4-5.7]	185 (74.9) [69.1-80.0]	36 (14.6) [10.7-19.5]	19 (7.7) [5.0-11.7]
5	5 (1.9) [0.8-4.3]	244 (91.0) [87.0-93.9]	16 (6.0) [3.7-9.5]	3 (1.1) [0.4-3.2]
9	3 (1.0) [0.3-2.9]	264 (86.9) [82.6-90.2]	30 (9.9) [7.0-13.7]	7 (2.3) [1.1-4.7]
(McCarthy) Body Fat % (McCarthy et al., 2006)				
1	44 (17.7) [13.4-22.9]	157 (63.1) [56.9-68.8]	35 (14.1) [10.3-18.9]	13 (5.2) [3.1-8.7]
5	53 (19.7) [21.1-31.1]	193 (71.8) [60.7-71.5]	17 (6.3) [3.7-9.2]	6 (2.2) [1.0-4.4]
9	29 (9.1) [11.6-19.2]	215 (67.2) [58.0-68.2]	40 (12.5) [8.3-15.0]	36 (11.3) [7.8-14.3]

[a] WHO = z-score of <-2SD IOTF = equivalent to BMI at age 18 of <18.5 CDC = z-score <-2 Body Fat = ranging from 0-16% depending on age
[b] WHO = z-score of ≥-2 and ≤+1SD IOTF = equivalent to BMI at age 18 of ≥18.5 and <25 CDC = ≥-2 and ≤+1 Body Fat = ranging from 15-31% depending on age
[c] WHO = z-score of >+1SD IOTF = equivalent to BMI at age 18 of ≥25 and ≤30 CDC = z-score >+1 to ≤+2 Body Fat = ranging from 24-34%, depending on age
[d] WHO = z-score of >+2SD IOTF = equivalent to BMI at age 18 of >30 CDC = z-score >+2 Body Fat = ranging from 28+% depending on age

5.3.5 Kappa table: comparison of different methods of defining weight status assessed by weighted kappa

Agreement between the various methods, assessed by weighted kappa analysis, was generally low, though worse for boys than girls (Table 5-7). In boys, the majority of comparisons yielded slight to moderate agreement with the only agreement classified as 'substantial' being the Grade 5 and 9 comparisons between WHO BMI-for-age and Cole/IOTF BMI-for-age. All three comparisons of weight or BMI-based assessments with body fat assessment produced agreements which were either slight or fair.

In girls, all agreements between methods were either moderate or substantial (Landis and Koch, 1977) with the exception of the Grade 1 Cole/IOTF BMI-for-age and CDC weight-for-age comparison and Grade 1 and 5 body fat versus CDC weight-for-age which were classified as fair agreement.

Table 5-7 Comparison between methods used to define weight status. Weighted kappas interpreted using Landis and Koch (Landis and Koch, 1977)

	Boys			Girls		
School grade	Kappa	Confidence interval	Kappa interpretation (Landis and Koch, 1977)	Kappa	Confidence interval	Kappa interpretation (Landis and Koch, 1977)
WHO BAZ/Cole-IOTF BAZ (de Onis et al., 2007)/(Cole et al., 2000, Cole et al., 2007)						
1	0.41	0.19 – 0.62	Fair	0.54	0.39 – 0.69	Moderate
5	0.65	0.54– 0.76	Substantial	0.61	0.42 – 0.79	Moderate
9	0.66	0.46– 0.86	Substantial	0.80	0.72 – 0.88	Substantial
WHO BAZ/BODY FAT (de Onis et al., 2007)/(McCarthy et al., 2006)						
1	0.34	0.20 – 0.48	Fair	0.42	0.23 – 0.61	Moderate
5	0.27	0.11 – 0.44	Fair	0.44	0.29 – 0.58	Moderate
9	0.13	0.06 – 0.20	Slight	0.68	0.54 – 0.81	Substantial
Cole-IOTF BAZ/ BODY FAT (Cole et al., 2000, Cole et al., 2007)/(McCarthy et al., 2006)						
1	0.27	0.09 – 0.45	Fair	0.51	0.39 – 0.63	Moderate
5	0.38	0.24 – 0.52	Fair	0.62	0.45 – 0.79	Substantial
9	0.24	0.03 – 0.46	Fair	0.70	0.55 – 0.86	Substantial
WHO BAZ/WAZ (de Onis et al., 2007)/(WHO, 1986)						
1	0.42	0.30 – 0.53	Moderate	0.49	0.36 – 0.61	Moderate
5	0.41	0.24 – 0.59	Moderate	0.52	0.35 – 0.69	Moderate
9	0.39	0.23 – 0.55	Fair	0.49	0.34 – 0.65	Moderate
Cole-IOTF BAZ/WAZ (Cole et al., 2000, Cole et al., 2007)/(WHO, 1986)						
1	0.34	0.12 – 0.57	Fair	0.35	0.21 – 0.50	Fair
5	0.42	0.22 – 0.62	Moderate	0.44	0.23 – 0.65	Moderate
9	0.55	0.31 – 0.78	Moderate	0.49	0.45 – 0.53	Moderate
BODY FAT/WAZ (McCarthy et al., 2006)/(WHO, 1986)						
1	0.32	0.08 – 0.56	Fair	0.39	0.17 – 0.62	Fair
5	0.15	0.003 – 0.30	Slight	0.28	0.16 – 0.39	Fair
9	0.15	0.09 – 0.22	Slight	0.44	0.27 – 0.61	Moderate

5.3.6 Discussion

5.3.6.1 Age- and gender-related differences in weight status and body fatness

Using the Cole/IOTF reference (Cole et al., 2000, Cole et al., 2007) combined overweight and obesity in this sample was 3.4%, 5.2% and 6.1% for boys and 9.2%, 9.7% and 22.7% for girls in grades 1, 5 and 9 respectively. The hypothesised prevalence of overweight and obesity (see Chapter 2: Aims) was 3-10% at age 7 years and 25-50% at age 15 years, therefore in boys, prevalence of overweight and obesity was lower than hypothesised whereas in girls the hypothesis was more accurate.

A systematic review which compared prevalence of overweight and obesity in young people aged 10-16 years in 34 countries (predominantly European countries although also including North America and Canada) found the highest prevalence of overweight and obesity to be in Malta at 25.4% and 7.9% respectively, closely followed by the US at 25.1% and 6.8% respectively (Janssen et al., 2005) (defined by Cole 2000 international body mass index standards (Cole et al., 2000)). Recent data from the Health Survey for England (HSE) show combined overweight and obesity in English children and adolescents aged 2-15 years to be 31% and 29% in boys and girls respectively (HSE, 2011) (defined using UK national reference (Cole et al., 1995)).

Although the prevalence estimates in the present study, especially in the boys, may appear small when compared to western samples, the results remain worrying given that the study population live in a rural area of sub-saharan Africa which still has high levels of undernutrition and a high prevalence of HIV, therefore the prospect of overweight and obesity also posing a problem means the area is vulnerable to a double burden of disease; both under and overnutrition, communicable and non-communicable diseases.

A previous study of adults living in this same area provides evidence that overweight and obesity are already a significant problem within adults in this region; in a sample of 2,543 men (25-54 years) and women (25-49 years) prevalence of overweight and obesity was 58% and 32% respectively while HIV prevalence was 35% (Barnighausen et al., 2008). Given these alarming results it is extremely important that interventions are developed to provide the most effective means of preventing further increases in overweight/obesity to bring an end to the progression of this epidemic and its persistence into the next generation.

A recent cross-sectional study carried out in South Africa found similar results to the present study in that combined overweight and obesity prevalence (using Cole/IOTF cut offs) was very low in boys, approximately 4-5% in late adolescence, but that in girls it increased with age and reached 25% by this time (Kimani-Murage et al., 2010).

In the present study girls appear to be at higher risk for overweight and obesity than boys. Girls in grade 9 had the highest prevalence of overweight and obesity and it may be plausible that interventions are best focussed on girls at some point between grade 5 and 9 before the most significant transition to overweight takes place. Further research is required to determine the most effective intervention and at which age it should be implemented.

5.3.6.2 Differences between use of different anthropometric methods for defining weight status and body fatness

In the present study the simple anthropometric methods used to define weight status produced estimates of unhealthy weight status which were markedly lower than estimates derived from body fatness measures; this discrepancy was greater in boys than girls. Agreement between definitions based on the simple proxies for body fatness and body fatness assessments were only 'fair' (Landis and Koch, 1977) in the boys and 'moderate - substantial' (Landis and Koch, 1977) in the girls. Simple anthropometric definitions of overweight and obesity are known to define high body fat conservatively (Monasta et al., 2011), and the Cole/IOTF obesity definition is not equivalent in boys and girls (Monasta et al., 2011). It is not clear why greater agreement was observed between anthropometric and body composition methods in girls than boys in the present study, but this difference between the sexes applied to most of the anthropometric methods used, extending beyond the expected sex-related bias associated with the Cole/IOTF obesity definition (Monasta et al., 2011). This issue merits further research as it would have important implications for future nutritional surveillance. Our study suggests that anthropometric nutritional surveillance would be more accurate in South African girls than boys given the better agreement in girls compared to boys.

Given the present results it may be possible that body fatness measures are more informative than simple proxies when assessing nutritional status, providing more realistic estimates of the prevalence of unhealthy weight status and avoiding the tendency of BMI based definitions to underestimate the prevalence of obesity. Body fatness measures should perhaps be considered as preferred alternatives to simple weight based measures in clinical settings and in public health applications such as surveillance. The use of bio-impedance as a field method is already widely used in surveillance of nutritional status throughout the developed world (Haroun et al., 2009a, Mueller et al., 2004, Deurenberg et al., 1990) and it may be helpful in future surveillance of nutritional status in low- and middle-income countries.

Comparisons with other studies

I am unaware of any studies which have compared the same approaches to defining weight status in rural South African children and adolescents. Few studies have considered definitions using a body composition reference method, or have compared assessments across the range of weight status (including both underweight and overweight/obesity), and even fewer have been able to evaluate the relatively new Cole et al approach to defining thinness. El-Ghaziri et al (2011) compared the same anthropometric methods for defining weight status in Kuwaiti adolescents: they found that the international approaches (Cole et al 2007, IOTF 2000, WHO 2007 and CDC-2000) agreed well with each other, however in the present study there were noticeable differences between these measures. Other studies have compared local and international references in children and adolescents, but with few studies from low - middle income countries and rural areas (Baya Botti et al., 2010, Kulaga et al., 2010).

A recent systematic review (Reilly et al., 2010c) found that the use of BMI-for-age with the Cole 2007 and IOTF 2000 methods was a highly conservative approach to defining obesity, with generally much lower estimates of obesity prevalence when used in school-aged children than when national reference data and definitions were used. Monasta et al used data from children in the Czech republic and found large differences in prevalence of overweight between Cole 2007 and IOTF 2000 versus WHO 2007 references, with Cole 2007 and IOTF 2000 diagnosing considerably higher prevalence of overweight compared to WHO Reference 2007. Their study called for urgent attention to determine the optimal

BMI cut offs for WHO reference 2007 to define overweight and obesity (Monasta et al., 2011).

South Africa currently uses several BMI references as the method of choice in surveillance of underweight, overweight and obesity (WHO 2007, WHO/National Centre for Health Statistics 1977, WHO/CDC 1977, IOTF 2000)(Armstrong et al., 2006, Armstrong et al., 2011, Monyeki et al., 1999, Puckree et al., 2011, Norris et al., 2009).

Recent South African prevalence studies have used anthropometric methods exclusively, the BMI-for-age NCHS/WHO Growth reference 1977 data for underweight and the IOTF approach for overweight/obesity (Reddy et al., 2009, Armstrong et al., 2011, Kimani-Murage et al., 2010). These studies all used simple proxy measures for body composition and none have used the new Cole et al thinness definition (Cole et al., 2007). One of the most recent South African studies, which is similar to the present study, was carried out within the rural Agincourt DSA amongst children aged 1-20 years (Kimani-Murage et al., 2010, Kimani-Murage, 2013). In addition to BMI, waist circumference was also measured, but no assessment of body fat was made. Combined overweight and obesity prevalence in this sample was found to be low in boys but significantly higher in girls during the adolescent years, reaching a peak of around 25% in late adolescence (age 18 years). Central obesity was used to define risk of metabolic disease and was measured by waist circumference; results showed girls had significantly higher risk of metabolic disease than boys, 16% vs 1% and that risk increased with pubertal stage. In line with the present study, these results demonstrated highest levels of overweight and obesity in the older female age groups, with girls displaying a higher prevalence of overweight and obesity than boys from age 7 onwards (Kimani-Murage et al., 2010).

Study strengths and weaknesses

The present study recruited a large representative sample of school children and adolescents and provides data across three different age groups. The sample was collected from a large area (400km^2) including children in rural, peri-urban and urban areas.

All fieldwork was carried out by the same fieldworkers with each assigned to a specific task in order to reduce intra-observer differences in data collection, and the same equipment was used for measurement of all participants.

There is a lack of prevalence data in this area and therefore these findings provide useful evidence of weight status within this region. Body fat was estimated by bio-impedance, providing novel results, given that previous studies in this area have not used this technique and have predominantly used more basic proxy measures. Pubertal status was not measured given the limited time and the impracticality of assessment within the school setting; in hindsight this may have been a useful measure and a self assessment technique could have been used. This may be something to consider in any future studies within this area and would allow comparison with results of other South African studies (Kimani-Murage et al., 2010, Cameron et al., 2009). Use of a non-invasive, self-report method would have been practical and appropriate here, however, debate remains as to the accuracy of such an approach (Norris and Richter, 2008).

The present study was novel as many of the constructs and definitions used are very new (e.g., Cole et al thinness definition (Cole et al., 2007)), with only limited evidence on their use to date, particularly in rural African populations. In addition, a great strength of the present study was the use of a measure of body fat as well as anthropometric measures, which are proxies for body fatness. The availability of body fatness data allowed us to deal with the issue of the validity of the simple anthropometric definitions, whereas previous studies have generally compared anthropometric definitions of unknown validity. The present study also recruited a relatively high proportion of the total DSA population in each age group (Table 5-2) and therefore can be considered relatively representative.

The appropriateness of all anthropometric and body composition methods in particular for use in specific ethnic groups is a controversial issue (Shaw et al., 2007). The extent to which reference data for weight, BMI or body fat should be ethnic-specific is not clear at present. One study comparing Asian and Caucasian children found significant ethnic differences in body composition between the two groups; at a given percentage of body fat Asian children had a BMI 3 - 6 units lower than their Caucasian counterparts. A high proportion of these children with a body fat classifying them as obese (body fat >25%

boys and >30% girls) were not identified as obese using WHO or IOTF references (one third and one half respectively) (Liu et al., 2011). An important issue is that all recommended methods for children and adolescents are universal, the current study therefore serves to indicate that this approach has possible limitations in certain ethnic groups.

It is possible that the bio-impedance estimates of fatness are biased in a sex-specific manner as bio-impedance analysis errors can be very different (magnitude and direction) in boys compared to girls (Reilly et al., 2010b). The use of the McCarthy (2006) references for body fat may have led to an over- or underestimation of body fat in the present sample, given that the reference was initially developed on Caucasian children and ethnic differences in body fat have previously been reported (Shaw et al., 2007). These ethnic differences, which show children and adolescents of South Asian and African-Caribbean ethnicity to have a higher percentage of body fat than those of white ethnicity may have an important role when using body fat measures to determine risk of obesity related diseases such as type 2 diabetes (Shaw et al., 2007).

The tentative recommendation from the present study to use a measure of body composition as opposed to a proxy could be problematic in low – middle income countries, especially rural areas, given limited resources. Bio-impedance is probably the least expensive field option but is more costly than equipment required for simple proxy measures of body composition, which are usually based on weight and height. However, the equipment used here provided both a weight measure and a body fat estimate meaning multiple measurements were not necessary and time was saved. Further, measures of body fatness may be more informative than simple anthropometry: one study showed that body fat from impedance allowed detection of associations between sedentary behaviour and fatness whereas simple proxies such as BMI and waist measures did not (Basterfield et al., 2012b). As the burden of non-communicable diseases (NCDs) grows in low and middle-income countries, the extra cost of bio-impedance may be justified in future population surveillance.

The anthropometric methods used for defining unhealthy weight status in children and adolescents do not produce equivalent assessments when applied in rural South Africa. Moreover, agreement between proxy measures of unhealthy weight status and measures of body fatness was generally low, with very conservative estimates of unhealthy weight status arising from the weight- and BMI-based measures. Bio-impedance measures of body fatness probably produce a more realistic estimate of the prevalence of unhealthy weight status.

5.4 Stunting defined by height-for-age

Height-for-age is often used to determine a child's status with regards to chronic undernutrition, where stunted children are those with a height-for-age z-score of <-2, although they may have a normal weight for their height. This form of undernutrition should not be confused with severe acute malnutrition where low weight-for-height or low MUAC are the variables of interest but where height-for-age may be normal (Waterlow, 1972, Waterlow, 2008). These different forms of undernutrition (chronic and acute) have different aetiologies and are associated with different morbidities (Dewey and Begum, 2011, Uauy et al., 2012). The vast majority (approx 80-90%) of individuals in the present sample were within the normal height-for-age range (between -1 and +1) across grades and genders. There appeared to be a higher likelihood of the remainder of individuals to be shorter/stunted rather than tall, particularly males (see Fig 5-15 and 5-16). Stunting amongst males was 16.0% (CI 14 - 25), 14.2% (CI 12 - 22) and 15.3% (CI 12 - 25) across grades 1, 5 and 9 respectively, whereas for girls the proportion of those stunted was 13.6% (11 - 21) in grade 1 females but less than 6% in grades 5 and 9 (CI 4 - 10 and 3 - 8 respectively).

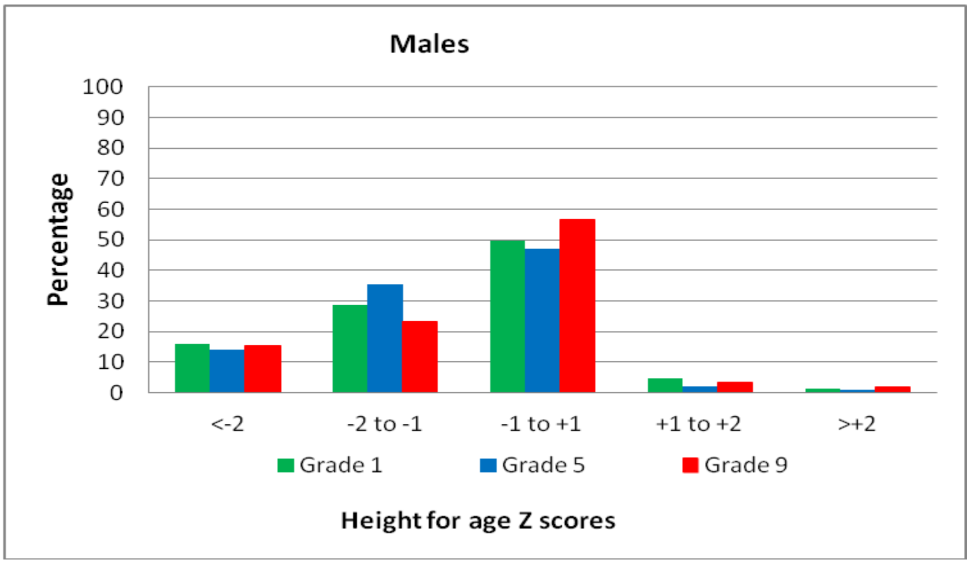

Figure 5-15 Height-for-age status of male study participants (WHO height-for-age)

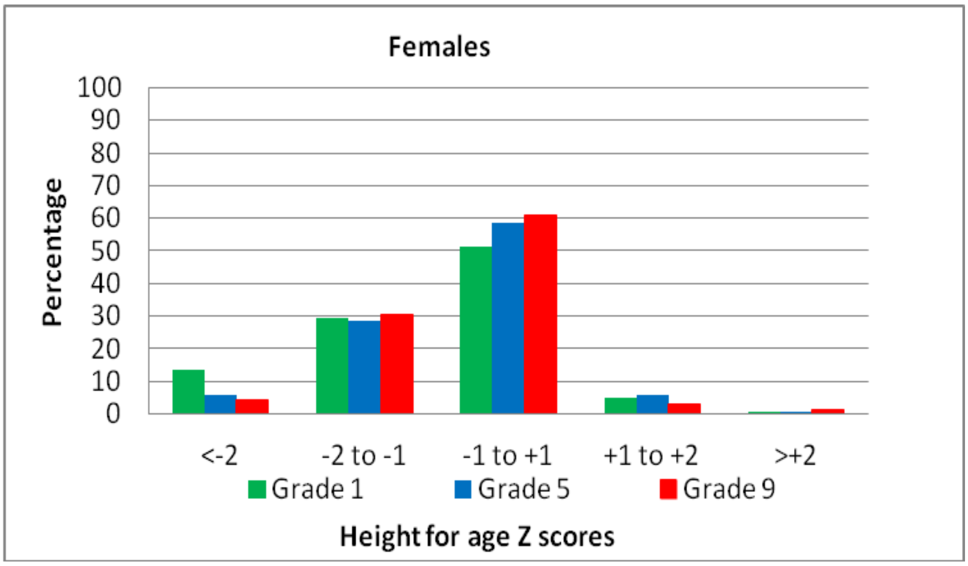

Figure 5-16 Height-for-age status of female study participants (WHO height-for-age)

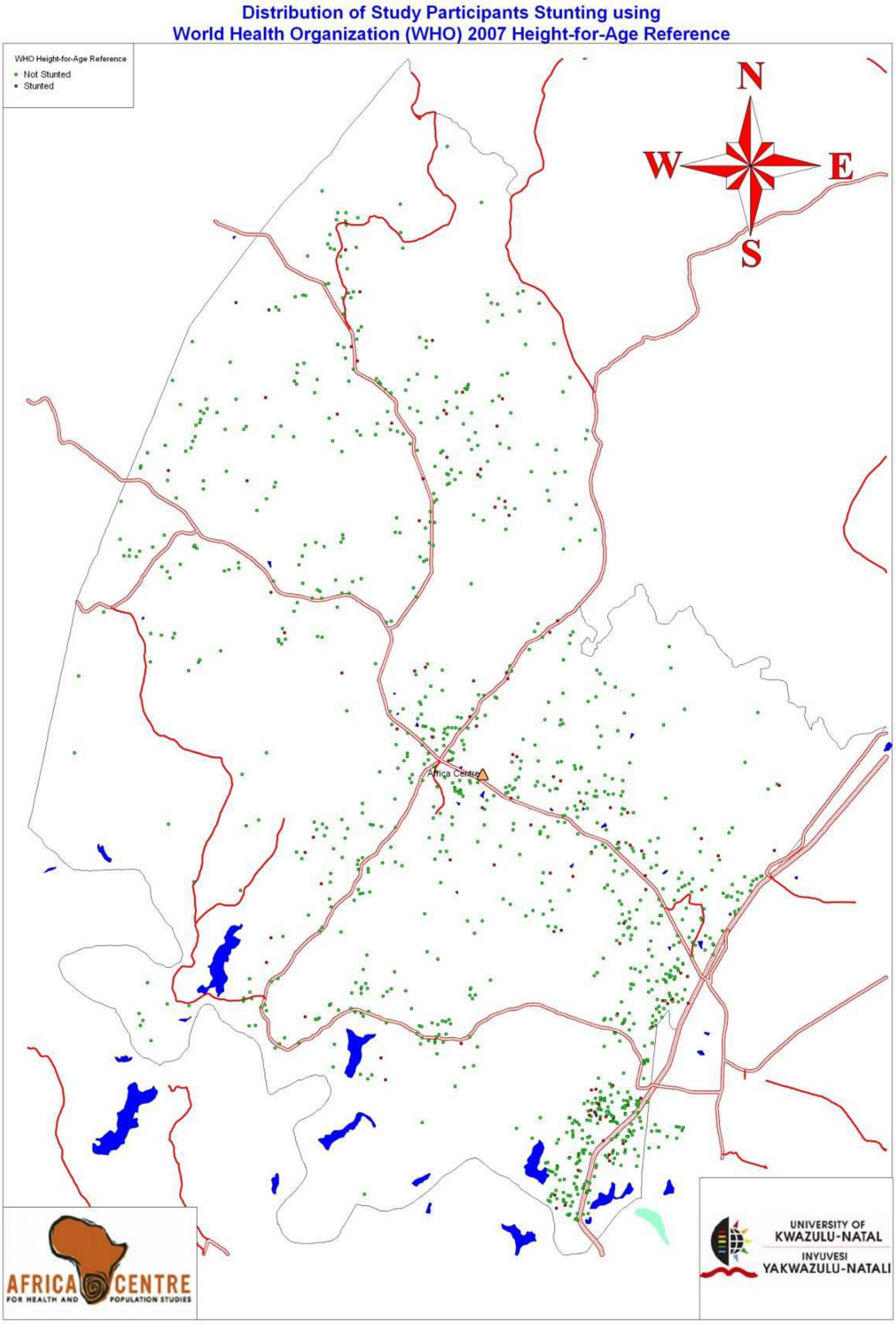

Figure 5-17 Stunting status of study participants by geographical distribution (WHO height-for-age) (Scale 1 : 57,470)

5.4.1 Discussion of stunting

Stunting can be described as retarded growth or a failure to reach one's genetic potential for height and is diagnosed by WHO standards as a height for age >2SD below the mean (Golden, 2009). Stunting remains a significant problem worldwide with one third of all children under age 5 years and living in developing countries classified as stunted; amounting to a staggering 178 million individuals (Black et al., 2008). Stunting is most commonly a result of retarded intrauterine growth, inadequate nutrition in the first two years of life or frequent infections in early life (Frongillo, 1999).

In 1989 Karlberg et al developed a biological mathematical model for human growth, this model is named the Infancy, Childhood and Puberty (ICP) model and is used to track growth from the intrauterine stage up to and including puberty (Karlberg, 1989a). Each component (infancy, childhood and puberty) appears to be controlled by differing biological mechanisms which can be analysed mathematically. This model works on the basis that infancy is largely nutrition dependent, childhood is governed predominantly by growth hormone and puberty by the interaction between sex steroids and growth hormone (Tse et al., 1989). If growth disturbances occur at any of these stages it may not be possible for growth to 'catch-up' in subsequent stages. The intention of developing this model was to allow for detection and understanding of growth disturbances at the individual level in order to enable early intervention (Tse et al., 1989, Karlberg, 1989b).

Consequences of stunting include impaired health, educational attainment, economic performance and maternal reproductive capability (Dewey and Begum, 2011).

In the present study prevalence of stunting was higher for boys than girls in all age groups. In both sexes stunting was highest in the youngest age groups.

Of all the continents, prevalence of stunting is highest in Africa where 40% (57 million) children under the age of 5 years are classified as stunted compared to 31% (112 million) in Asia and 16% (9 million) in Latin America and the Caribbean (Black, Allen et al. 2008). Southern Africa itself has a stunting prevalence rate of 30% for children under 5 years of age (defined using WHO child growth standards) amounting to a total of 2 million children (Dewey and Begum, 2011). A meta-analyses of 16 studies from sub-saharan Africa found boys more likely to be stunted than girls with regard to both prevalence (40% vs 36%

respectively) and extent of stunting shown by mean z-score (-1.59 vs -1.46 respectively). An association was also found between likelihood of stunting and socio-economic status, however, this was not significant (Wamani et al., 2007), therefore this relationship may require further investigation.

A more recent study carried out in 570 children and adolescents aged 5 - 19 years in Nigeria found 17.4% of the sample to be stunted and identified attendance at public school, being part of a polygamous family, low maternal education and low social class as factors associated with an increased risk of stunting. Maternal education was the only significant variable and for this reason the authors suggest that encouraging female education may in turn improve health care behaviours and alleviate the high prevalence of stunting (Senbanjo et al., 2011).

Mushtaq et al undertook a study in Pakistan of 1,860 children aged 5-12 years and found prevalence of stunting to be 8%. Contrary to the results of the present study, stunting was found to increase with age and there was no association with sex (Mushtaq et al., 2011). This inconsistency in results between studies highlights the need for further research into risk factors of stunting.

It is not necessarily the short stature in stunting that causes health problems but rather it is that short stature can result from internal abnormalities; body composition is one of the factors which may be affected (Dewey and Begum, 2011, Black et al., 2008). One recent cross-sectional study carried out in South Africa aimed to address this complex issue and examined whether a relationship existed between stunting and other body composition measures (Motswagole, 2012). Measurements carried out in the study included body mass index, BMI-for-age z-score, sum of triceps and sub-scapular skin folds, waist circumference and waist : height ratio (WHtR) and comparisons were made between stunted and non stunted children (Motswagole, 2012). Two different study populations were used in this cross-sectional study and although a relationship was identified between stunting and WHtR such that all stunted groups had a WHtR over 0.41 (WHtR >0.41 is a cut off point given its association with increased risk for high blood pressure in children (Motswagole et al., 2011)), results were generally inconsistent for other measures and this highlights the difficulty of using alternative measures to identify risk (Motswagole, 2012).

A recent review suggests that as many countries are currently undergoing the nutrition transition and therefore experiencing increased levels of overweight it may be advisable to shift the main indicator of child health and chronic undernutrition to stunting rather than underweight as in many areas there are now low levels of underweight but a persistence of stunting and its accompanying consequences (Dewey and Begum, 2011). It may be beneficial to use the mathematical Infancy Childhood Puberty (ICP) model explained above to investigate this further.

6 Mid-upper arm circumference (MUAC) – descriptive results and analysis for potential use as a proxy for determining overweight or overfatness in children and adolescents

MUAC is most commonly used for identification of severe acute malnutrition in young children with WHO cut offs available for children aged 6 - 60 months (WHO, 2009b). Given that this is the primary use of MUAC, the majority of research to date has focussed largely on young children with a lack of research on the potential for MUAC in older children and adolescents.

To our knowledge no previous study has specifically tested the theory that MUAC may be used as an indicator of overweight status and therefore the present study aimed to conduct an analysis to assess agreement between measures of MUAC and both body weight and body fat status to determine whether a relationship exists and cut points could be developed with a focus on overweight and overfat.

MUAC is known to have a high practical utility often superior to that of weight and height measurements which can be difficult to measure accurately in many settings globally and which require use of more complex equipment, as well as calculations in order to determine BMI (Dasgupta et al., 2010). However, the use of MUAC is well established across a variety of settings and is a method widely used throughout the developed world as a result of its simplicity.

As described in Chapter 4: Methods, mid-upper arm circumference (MUAC) was one of the anthropometric measurements used in the present study.

This chapter is split into 3 sections and includes:

1. Descriptive statistics of MUAC data

2. Results of a ROC curve analysis designed to assess potential use of MUAC to define overweight and overfat

3. Discussion of results

6.1 Descriptive statistics of MUAC data

Figure 6-1 shows a boxplot of the MUAC data collected from participants in the present study. Boys appeared to have slightly lower MUACs compared to girls in the same grade and girls generally displayed a wider range of measurements.

The WHO guidelines for detecting severe acute malnutrition are <115mm for children aged 6 - 60 months (WHO, 2009b).

There are no internationally agreed upon MUAC cut offs for children and adolescents aged 5 - 19 years; however recent guidelines for the nutritional care of HIV-infected children have proposed the following values for screening (pending formal validation)(WHO, 2009a):

- In children 5-9 years of age, a MUAC less than 129 mm (equivalent to a -3 z-score according to growth standards for 5 year old boys)

- In adolescents 10-14 years of age, a MUAC less than 160 mm

Only one individual in the present study would be classed as severely malnourished when using these guidelines; the outlying male in grade 5.

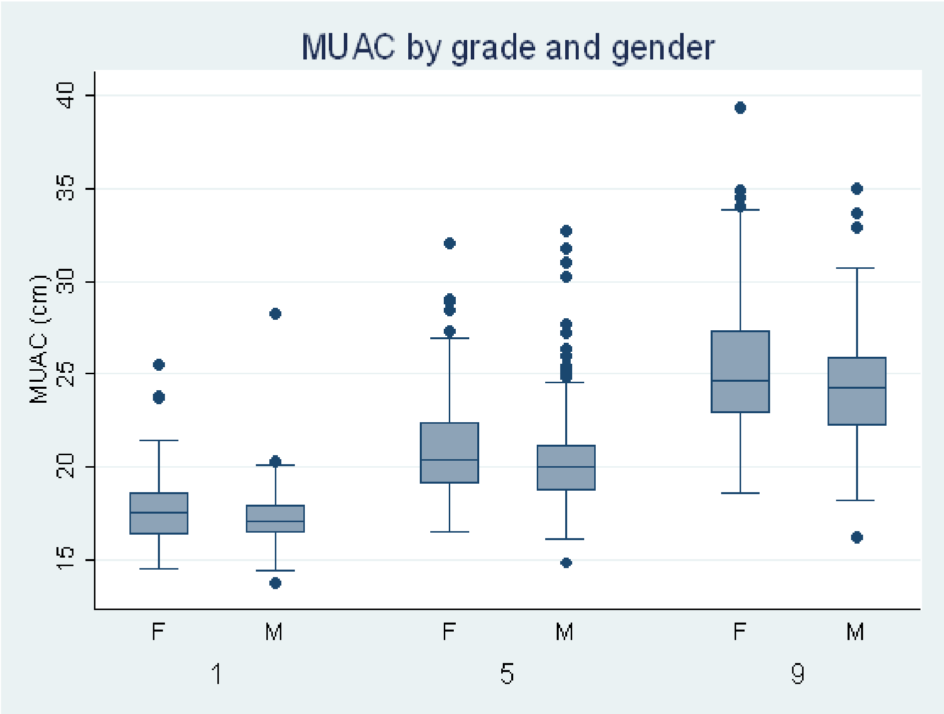

Figure 6-1 Boxplot of mid-upper arm circumference ranges by school grade and gender

6.2 Receiver operating characteristics (ROC) curve analysis of MUAC in order to determine potential use of MUAC for defining overweight and overfat

MUAC is an easy, quick, non invasive and inexpensive field measure most commonly used for identification of severe acute malnutrition in young children (WHO, 2009b). The MUAC is well established and is widely used throughout resource-limited settings as a result of its simplicity. To date, MUAC has been used largely in screening for undernutrition and internationally accepted cut offs are only available for children aged 6 - 60 months (WHO, 2009b). There is a dearth of research on the potential for MUAC as a screening tool for obesity, and a lack of research on its use in older children and adolescents. (Fernandez et al., 2010, Mei et al., 1997, Dasgupta et al., 2013, de Onis et al., 1997).

The present study therefore aimed to determine the accuracy of the MUAC for the assessment of overweight and overfatness in children and adolescents (see Chapter 4: Methods).

Receiver operating characteristic (ROC) analysis was used to test the ability of MUAC to identify those children and adolescents identified as overweight and overfat. ROC analysis allows researchers and clinicians to evaluate the ability of screening tools to discriminate individuals with a characteristic from individuals without the characteristic (Kraemer, 1992).

Separate tests were carried out for a relationship between MUAC and body fatness (overfat) and body weight (overweight). A detailed description of the ROC test is given in Chapter 4. For the purposes of analysis, participants were divided into sex-specific (male and female) and age-specific (5-9 years and 10-14 years) groups. These age-specific groups were chosen given that the WHO guidelines detailed also used these age groups (WHO, 2009a).

The initial ROC curve was used to determine the sensitivity and specificity of the relationship between the two variables where sensitivity is plotted against the specificity for each value of the test. ROC analysis is a non-parametric test, and the most common way to index the probability that a test will correctly classify participants is with the area under the curve (AUC). The AUC is a measure of accuracy and is indexed from 0 to 1 where 1 indicates a perfect test and ≤0.5 a worthless test (Zou et al., 2007).

The categories used to summarise accuracy in ROC analysis were as follows (Metz, 1978): 0.9 - 1 Excellent, 0.8 - 0.9 Good, 0.7 - 0.8 Fair, 0.6 - 0.7 Poor, 0.5 - 0.6 Fail.

A probability curve was then plotted to determine probability of being overweight/obese at each MUAC reading, the point at which the probability curve showed a marked increase is selected as a possible indicator. Based on the results of the ROC curve and the probability graph, two potential optimal operating points (OOP) were determined for each age and gender group and their accompanying data, with regards to probability, sensitivity, specificity and classification accuracy are also presented in Tables 6-2 and 6-3 for overfatness and overweight respectively.

6.2.1 Characteristics of study participants included in ROC analysis of MUAC

MUAC data from 978 participants was analysed, this included all individuals aged 5 -14 years from the main cross-sectional study. The sample included 481 aged 5 - 9 years (235 and 246 females and males respectively) and 497 aged 10 - 14 years (269 and 228 females and males respectively) (Table 6-1).

Table 6-1 Characteristics of study participants included in MUAC ROC analysis

Age group (years)	Sex	N	Age (years) Mean(SD)	Body Fat % Mean(SD)	BMI Z-score Mean(SD)
5-9	Female Male	235 248	7.2 (0.77) 7.2 (0.84)	19.5 (5.2) 17.2 (3.1)	-0.02 (0.99) -0.16 (0.97)
10-14	Female Male	269 228	11.6 (1.22) 11.8 (1.07)	21.3 (6.0) 13.4 (5.2)	-0.01 (1.01) -0.31 (1.02)

6.2.2 Analysis of ability of MUAC to classify excessive body fatness defined by McCarthy 2006 body fat reference (McCarthy et al., 2006)

Body fatness was defined using McCarthy 2006 body fat reference curves for children and adolescents and cut offs for excess fatness were age- and sex-specific (McCarthy et al., 2006).

AUC results from the ROC curve (see Figure 6-2) were ‘excellent’ for both girls and boys 10-14 years of age (0.97 and 0.98 respectively), however for girls and boys aged 5-9 years results were slightly lower, classified as ‘good’ (0.88) for girls and ‘poor’ (0.66) for boys.

In general, both sensitivity and specificity were reasonably high for the cut points chosen for all age and gender groups (see Table 6-2). The exceptions were found in the results for boys aged 5 - 9 years and girls aged 10 - 14 years. In boys 5 - 9 years sensitivity was very low at only 27% or 25%, depending on cut point used; this is in line with the AUC results for boys in this age group which were also low at 0.66 (classified as ‘Poor’ using the points system noted above). Girls aged 10-14 years showed 100% sensitivity but a lower specificity of 69% and 77% depending on the cut point chosen.

Percentages correctly classified using the chosen cut offs range from 72% up to 94%. Correct classification appeared to be higher in girls in the younger rather than the older age group (85%/87% vs 72%/79% respectively) but higher in boys in the older rather than the younger age group (93%/94% vs 75%79% respectively).

Based on analysis by ROC curve (Figure 6-2)and probability curve (Figure 6-3) the optimal MUAC cut offs to identify overfatness are proposed from present study data (defined by body fat reference (McCarthy et al., 2006)); at age 5-9 years 19.2cm/19.5cm and 18.4cm/18.7cm for girls and boys respectively and at age 10-14 years 22.0cm/22.6cm and 23.2/23.6cm for girls and boys respectively.

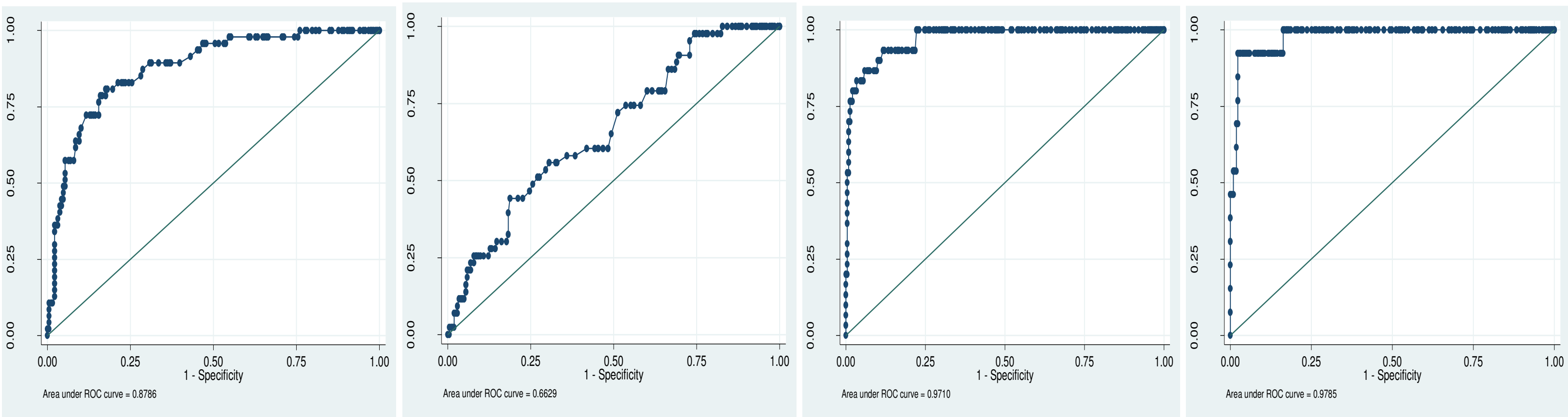

Figure 6-2 ROC curve of MUAC vs body fatness (girls age 5-9 years, boys age 5-9 years, girls age 10-14 years and boys age 10-14 years respectively)

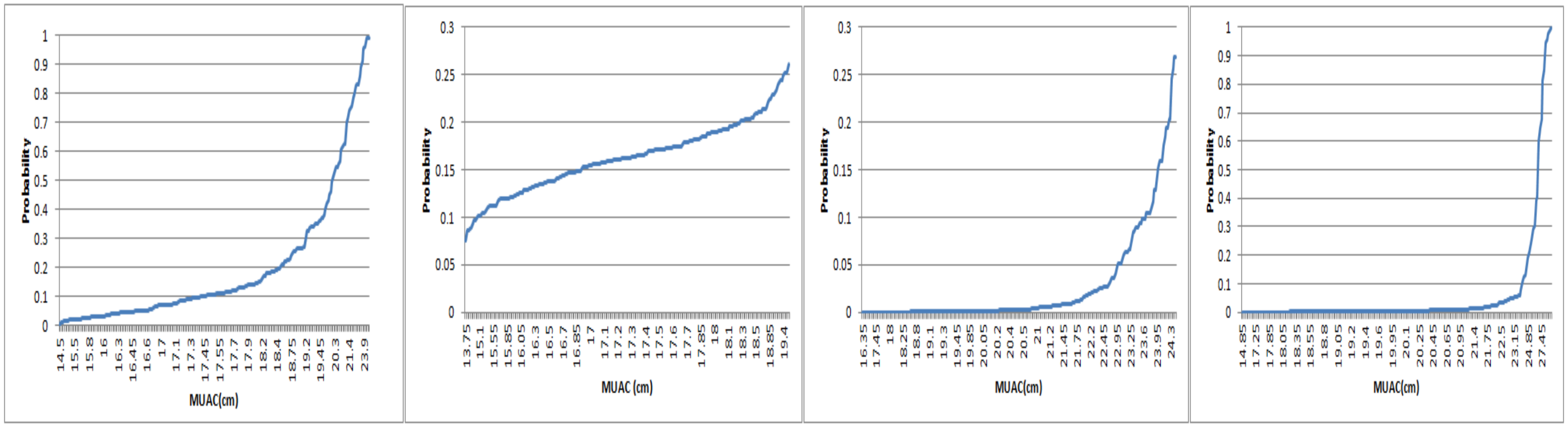

Figure 6-3 Probability curve of MUAC vs overfat (girls age 5-9 years boys age 5-9 years, girls age 10-14 years and boys age 10-14 years respectively)

MUAC (cm)	Predicted probability	Logit (p)	Sensitivity (%)	Specificity (%)	Correctly classified (%)
Girls 5-9					
19.2	0.32	-16.71	63.8	90.4	85.1
19.45	0.37	-16.71	57.5	94.7	87.2
Boys 5-9					
18.4	0.21	-5.94	27.9	85.7	75.6
18.65	0.22	-5.94	25.6	90.6	79.3
Girls 10-14					
22.0	0.02	-30.72	100	69	72.5
22.6	0.03	-30.72	100	77.4	79.9
Boys 10-14					
23.2	0.06	-22.1	92.3	94.0	93.9
23.6	0.08	-22.1	92.3	94.9	94.7

Table 6-2 Determining optimal operating point (OOP) for MUAC vs overfatness

6.2.3 Analysis of ability of MUAC to classify overweight (including obesity) status defined by WHO 2007 BMI-for-age reference (WHO, 2007)

Overweight (including obesity) was defined in the present study using the WHO 2007 BMI-for-age reference where overweight is classed as having a z-score >+1SD (equivalent to BMI 25 kg/m^2 at age 19 years)(WHO, 2007).

AUC results of the ROC curve (Figure 6-4) were ‘excellent’ for both girls and boys at both age groups 5 - 9 and 10 - 14 years of age. For girls and boys aged 5 - 9 years AUC results were 0.96 and 0.90 respectively while for girls and boys aged 10 - 14 years they were 0.94 and 0.97 respectively.

Sensitivity and specificity values were generally high for the age- and gender-specific cut points proposed (76-97%) (Table 6-3), however as for the body fat analysis the exception to this was boys aged 5 - 9 years who showed the lowest sensitivity of only 68% and 64% for the two cut points chosen.

Percentages correctly classified using the proposed cut points ranged from 80% up to 92% across age and gender groups (Table 6-3).

Based on the ROC analysis (Figure 6-4) and probability curve (Figure 6-5) the optimal MUAC cut offs for identification of overweight status (defined by WHO 2007 BMI reference(WHO, 2007)) were as follows; age 5 - 9 years 18.3cm/18.85cm and 18.4cm/18.6cm for girls and boys respectively and at age 10 - 14 years 22.45cm/22.8cm and 22.15cm/23.15cm for girls and boys respectively.

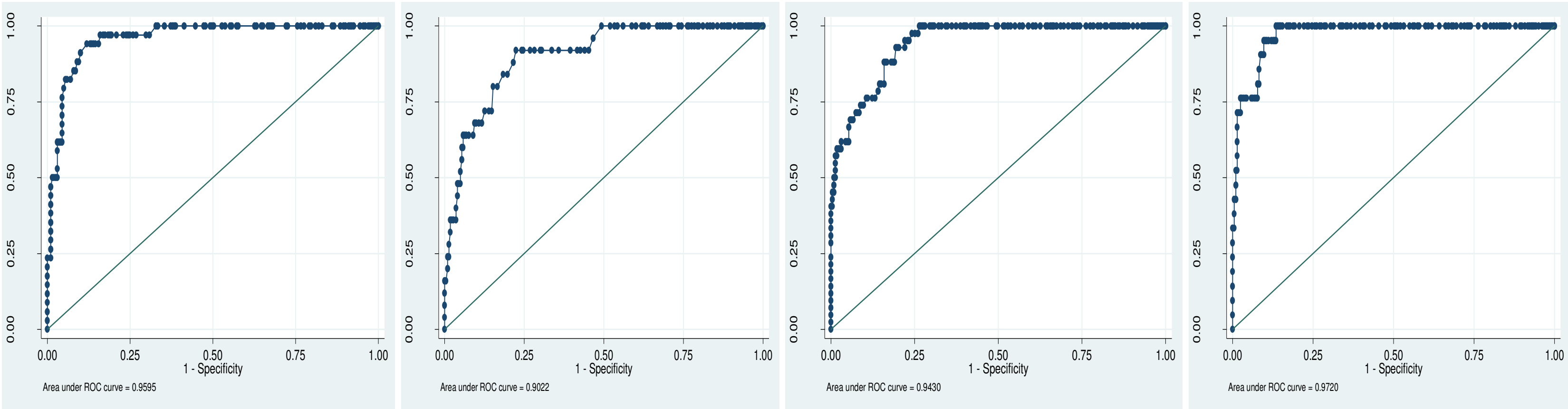

Figure 6-4 ROC curve of MUAC vs weight status (girls age 5-9 years, boys age 5-9 years, girls age 10-14 years, boys age 10-14 years respectively)

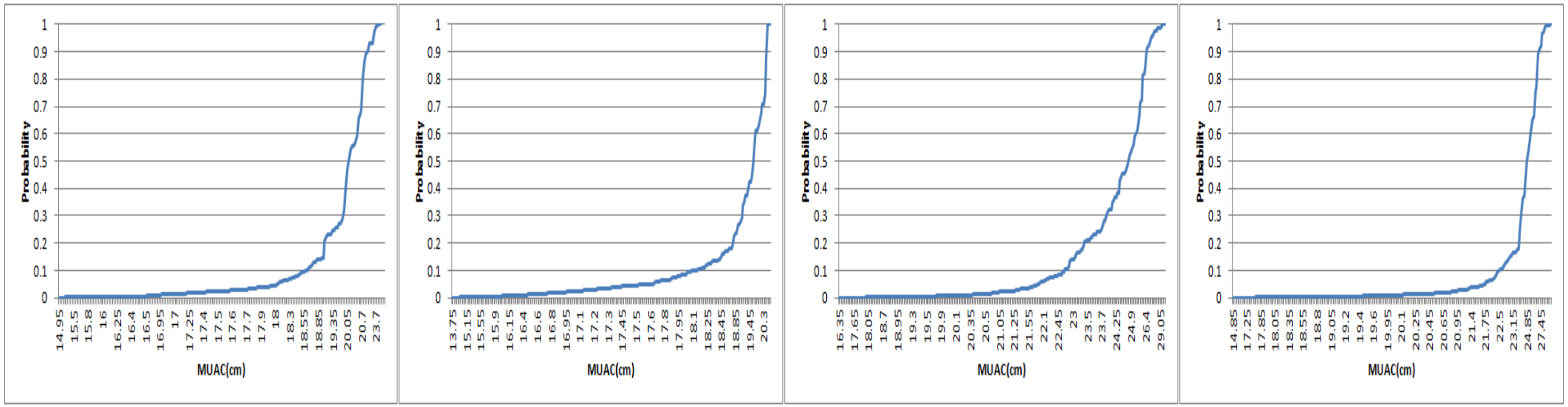

Figure 6-5 Probability curve of MUAC vs weight status (girls age 5-9 years, boys age 5-9 years, girls age 10-14 years, boys age10-14 years respectively)

MUAC (cm)	Predicted Probability	Logit(p)	Sensitivity(%)	Specificity(%)	Correctly Classified(%)
Grils 5-9					
18.3	0.07	-28.5	97.06	79.10	81.7
18.85	0.14	-28.5	94.12	88.06	88.94
Boys 5-9					
18.4	0.14	-27.7	68.0	89.24	87.10
18.6	0.18	-27.7	64.0	93.27	90.32
Girls 10-14					
22.45	0.08	-25.4	92.86	77.97	80.3
22.8	0.12	-25.4	88.1	81.06	82.16
Boys 10-14					
22.15	0.07	-23.5	95.24	89.86	90.35
23.15	0.17	-23.5	76.19	76.19	92.54

Table 6-3 Determining optimal operating point (OOP) for MUAC vs weight status

6.3 Discussion of MUAC analysis

Main findings

As previously described, MUAC is most commonly used for identification of severe acute malnutrition in young children with WHO cut offs available for children aged 6 - 60 months (WHO, 2009b). Using the current WHO guidelines, only one individual in the present study was identified as presenting with severe acute malnutrition (<115mm): these results may be taken to indicate that severe acute malnutrition is not a problem in this area, however, as already discussed, data on stunting and underweight in this sample indicate levels of chronic undernutrition to be significantly higher.

Given that MUAC is a simple, non invasive and inexpensive field measure it may have the potential to be used for the identification of overweight as well as undernutrition. With the aid of a ROC curve analysis and a probability curve, age- and sex-specific cut points were chosen for both boys and girls aged 5 - 9 years and 10 - 14 years.

In the present study the classification accuracy of MUAC (as indicated by ROC curve AUC statistics) was high for both overweight and obesity as defined by BMI, and for overfatness as defined by bio-electrical impedance. However, classification accuracy was higher for BMI (a weight-based measure) than for body fatness. Sensitivity and specificity were generally high, but lowest in boys aged 5 - 9 years. The present study provides stronger evidence for potential future use of MUAC in adolescents of both sexes, and in girls rather than boys during childhood, but the MUAC cutpoints proposed from the present study should ideally be tested in an independent sample in order to provide confidence in the ability of MUAC to detect overweight and overfatness.

Implications

Our findings suggest that MUAC has potential as a proxy measure for both overweight and overfat in children and adolescents in rural South Africa. Measurement of MUAC is a very simple, widely used and practical proxy for undernutrition (Briend et al., 2012, Goossens et al., 2012), but the present study suggests that it might have future potential for both public health surveillance of obesity (e.g., prevalence, secular trends), and for clinical use (e.g., identification of children or adolescents who might benefit from further assessment and/or clinical management).

The relative importance of sensitivity and specificity will depend on the precise application (Parikh et al., 2008), for example, a clinical diagnostic tool has to have high specificity in order to avoid diagnosing the non-obese as obese and offering treatment unnecessarily. However, when the results are to be used for a public health application such as prevalence estimation arguably a high sensitivity is more important, to avoid underestimation of prevalence (Reilly et al., 2010c). In the present study both sensitivity and specificity were generally high therefore providing grounds for further research on the potential value of MUAC for assessment of overweight and overfatness in both clinical and public health settings.

Comparisons with other studies

Few studies have measured MUAC in large samples, and the majority of research to date has focussed on children under 5 years of age and predominantly on the use of MUAC for the assessment of undernutrition (WHO, 2009b, Dasgupta et al., 2013, Mei et al., 1997, de Onis et al., 1997). One recent study attempted to develop a MUAC-for-height reference in children aged 5 years and under (Mei et al., 1997) and another previous study carried out research in adolescents to determine whether a relationship existed between MUAC and BMI-for-age (Dasgupta et al., 2010), but with a focus on undernutrition rather than overnutrition (Dasgupta et al., 2010). To our knowledge no previous study has specifically tested whether MUAC has value as a simple indicator of overnutrition.

Two systematic reviews have summarised the accuracy of simple anthropometric measures (BMI for age and waist circumference) for classifying high body fatness and/or cardiometabolic risk factors among children and adolescents (Reilly et al., 2002, Reilly et al., 2010c). Many of the eligible studies in the most recent systematic review (Reilly et al., 2010c) used ROC-AUC analysis to determine the classification accuracy of BMI and waist circumference, and for the majority of these studies (summarised in Table 6-4), ROC-AUC values were lower than for the MUAC ROC-AUC analyses in the present study; providing further support for the view that MUAC has potential as a simple anthropometric indicator of high BMI for age and overfatness.

Table 6-4 Comparison of AUC results from present study with those from previous studies assessing accuracy of anthropometric measures in identifying risk factors

Author	Aim	Sample	Country	Measure Used	AUC	
Present study	MUAC[1] for defining overweight	N= 978 5-14 years	South Africa	MUAC	Age 5-9 Girls 0.96 Boys 0.90	Age 10-14 Girls 0.94 Boys 0.97-
Present study	MUAC[1] for defining overfat	N= 978 5-14 years	South Africa	MUAC	Age 5-9 Girls 0.88 Boys 0.66	Age 10-14 Girls 0.97 Boys 0.98
Reilly (Reilly et al., 2010a)	BMI[2] vs WC[3] for obesity	N= 7,722 9-10 years	England	BMI WC	0.93 0.85	
Oliveira (Oliveira et al., 2006)	BMI[2] for diagnosing excess fatness	N= 418 9-18 years	Brazil	BMI (Cole/IOTF)	0.75	
Zimmerman (Zimmermann et al., 2004)	BMI[2] for diagnosing excess fatness	N= 2,431 6-12 years	Switzerland	BMI (Cole/IOTF)	0.80	
Neovius (Neovius et al., 2005)	BMI[2] vs WC[3] for defining excess fatness	N= 474 16-17 years	Sweden	BMI WC	0.97 0.96	
Neovius (Neovius et al., 2004)	BMI[2] for diagnosing excess fatness	N= 474 16-17 years	Sweden	BMI	Boys 0.82-0.98 Girls 0.80-0.99	
Mei (Mei et al., 2007)	Diagnostic accuracy of BMI[2]-for-age	N= 1196 5-18 years	US	BMI	5-11 years 0.96 12-18 years 0.97	
Mei (Mei et al., 2002)	Diagnostic accuracy of BMI[2]-for-age	N= 12,016 2-19 years	US	BMI	0.95	
Bedogni (Bedogni et al., 2003)	Diagnostic accuracy of BMI[2]-for-age	N= 986 8-12 years	Italy	BMI	0.94	
Taylor (Taylor et al., 2003)	Diagnostic accuracy of BMI[2]-for-age	N= 368 8-15 years	New Zealand	BMI	Boys 0.95 Girls 0.98	

[1]MUAC = Mid-upper arm circumference [2]BMI= body mass index [3]WC= waist circumference

Strengths and limitations

One limitation of the present study is that the optimal cut offs in the MUAC distribution were not cross-validated in an independent sample. Future cross-validation would be necessary to establish the value of MUAC for the assessment of overweight and overfatness, and the present study is perhaps best seen as a 'proof of concept' in that it establishes the potential value of MUAC. In the present study the analysis assessed the ability of MUAC to define overweight and obesity combined, however, future studies may assess the ability of defining obesity alone and determine how accurate MUAC would be for this.

The present study used the widely accepted and recommended BMI-for-age cut offs to define overweight (including obesity), but for overfatness the McCarthy body fat reference curve was used(McCarthy et al., 2006). The applicability of the McCarthy et al definitions of overfatness - based on a European population - to other populations is unclear at present, but I note that these definitions utilise what would generally be accepted as very high levels of body fatness in all populations (Lohman, 1993). The 'overfatness' definitions based on the McCarthy body fatness reference as used in the present study were age and sex specific. For 5 – 9 year olds; in girls the cut off ranges from 22-27% body fat, in boys 19-22%. For 10 – 14 year olds; in girls the cut off ranges from 28-30% and in boys 21-23%.

An alternative approach would have been to use a criterion method of body fatness measurement (a 3 or 4 component model) to define overfatness, but the criterion methods are not very practical for use in large samples in resource-limited settings (Wells and Fewtrell, 2006)

In summary, this study provides novel evidence that MUAC has the potential to be used in the screening of overnutrition and calls for further studies to investigate this concept in different populations.

Chapter 7

7 Lifestyle, physical activity and diet of rural South African children and adolescents

This chapter is split into 2 main sections.

Section 1 - Presents the descriptive results of the lifestyle questionnaire administered to all children and adolescents in the cross-sectional study (n=1519) and discusses these results.

Section 2 – Presents the descriptive results of the sub-sample study; this section includes

- Recruitment of sub-sample participants
- Results of the objective physical activity assessment carried out by accelerometry
- Results of dietary assessment administered using the 24 hour multiple pass dietary recall technique.
- Discussion of results

7.1 Results of lifestyle questionnaire administered to study participants

The following section provides data collected using the lifestyle questionnaire (see Appendix 10) which was administered to all study participants; a written description is provided and a table and graph of each variable by grade and gender.

Water collection (Figure 7-1)

Proportion of subjects collecting water was lower for those in higher school grades, this was seen in both boys and girls, however, a higher proportion of girls than boys reported water collection at each age point.

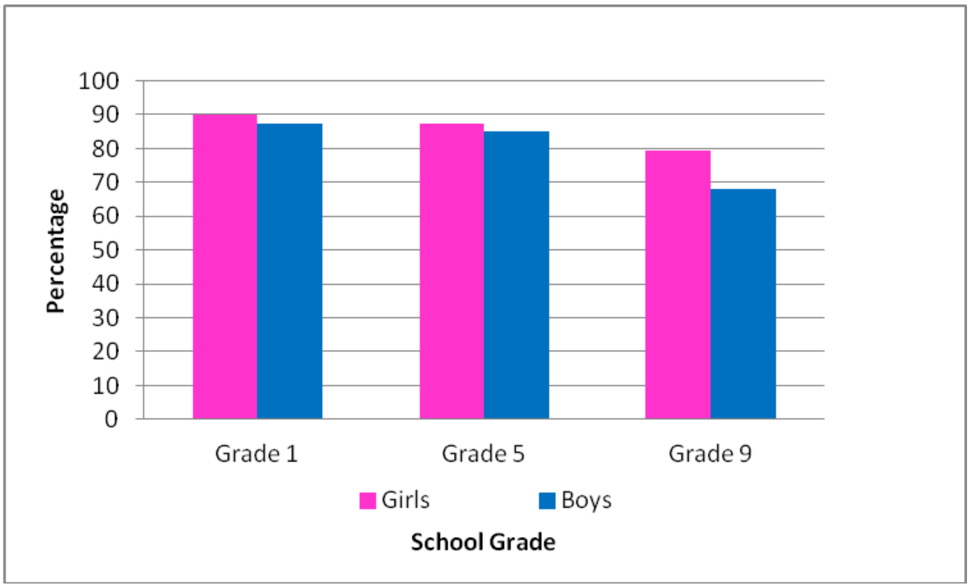

Figure 7-1 Water collection of study participants by grade and gender

Frequency of water collection by girls and boys (Figures 7-2 and 7-3)

The majority of participants collected water at least once a day. No participants reported collecting water at a frequency of less than once per week, therefore this category is not shown on the figures.

Most girls in all grades collected water at least once a day, this proportion was higher in grade 5 and 9 participants than in grade 1 (76% and 77% vs 59% respectively). Few girls collected water only once a week and a third of girls in grade 1 collect water 2 - 6 times a week.

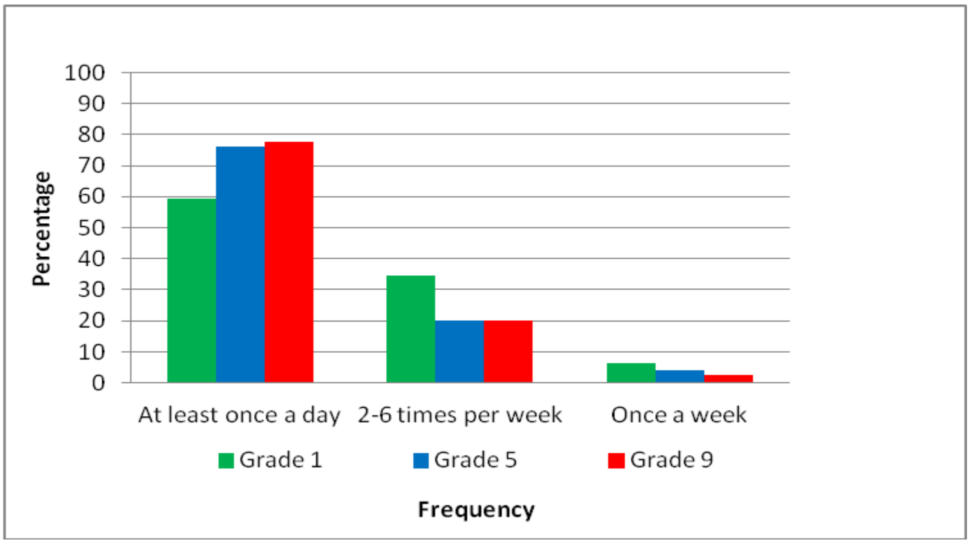

Figure 7-2 Frequency of water collection by study participants (girls)

Frequency of water collection in boys showed no obvious difference between grades, with frequency of collecting at least once per day ranging from 62-69% and approximately 20-30% reporting collecting 2 - 6 times per week. Less than 10% in all grades reported collecting water only once a week.

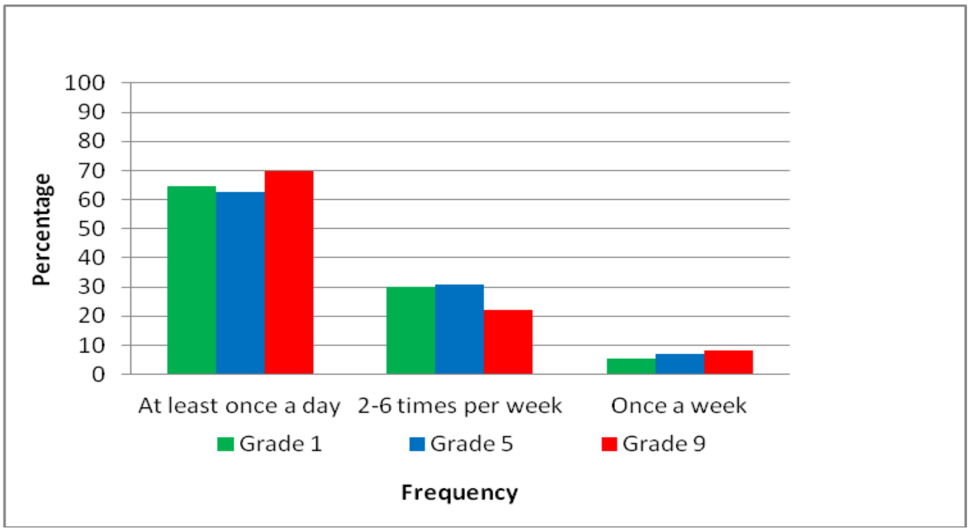

Figure 7-3 Frequency of water collection by study participants (boys)

Time taken to collect water (Table 7-1)

The reported time taken to collect water varied across the age groups and between sexes, the largest difference between the sexes was in grade 9 where boys reported spending an average of 19 minutes versus girls reporting an average of 28 minutes to travel one way to collect water.

Method of travel to school (Figure 7-4 and 7-5)

Of the total sample, only one grade 1 female and one grade 9 male reported travelling to school by bicycle, therefore this variable was omitted from the figure. The only other methods of travelling to school reported were walking or motor vehicle.

The majority of children in all age groups and in both sexes walked to school, with the highest levels for children in grade 5 and lowest for those in grade 1.

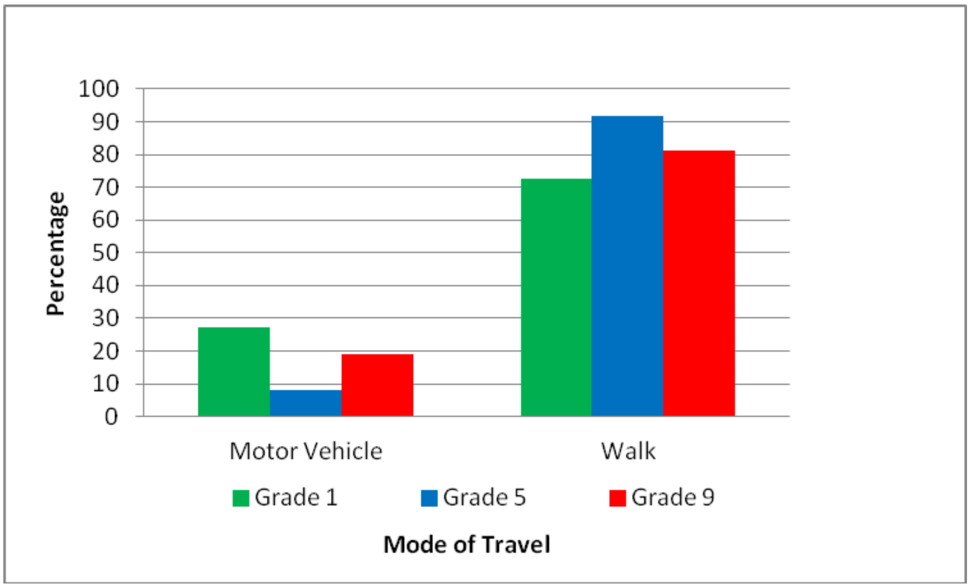

Figure 7-4 Method of travel to school by study participants (girls)

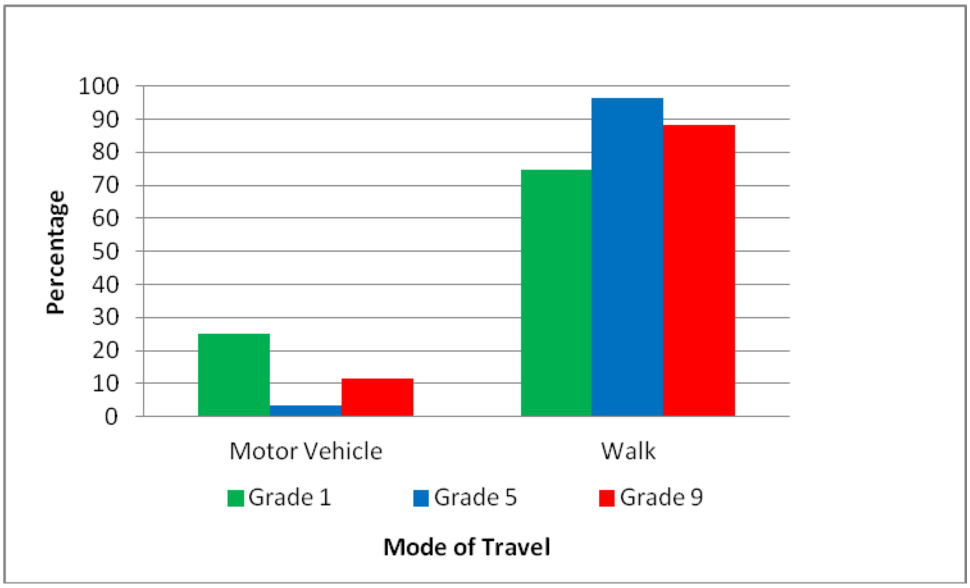

Figure 7-5 Method of travel to school by study participants (boys)

School journey time (Table 7-1)

The reported time taken to travel to school, one way, ranged from a mean (SD) of 29 (16) minutes in grade 5 girls up to 39 (25) minutes in grade 9 girls, with the longest time reported by females in grade 9.

Electricity at home (Figure 7-6)

Approximately 70 - 80% of participants in each grade reported having electricity at home.

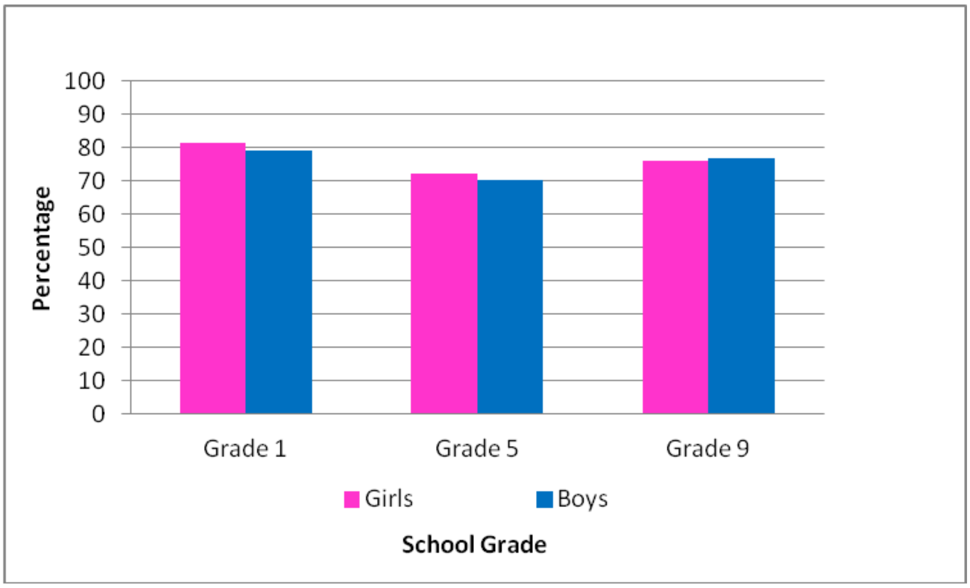

Figure 7-6 Availability of electricity at home for study participants by grade and gender

Television (TV) at home(Figure 7-7)

Similarly, approximately 70-80% of participants in each grade reported having a TV at home.

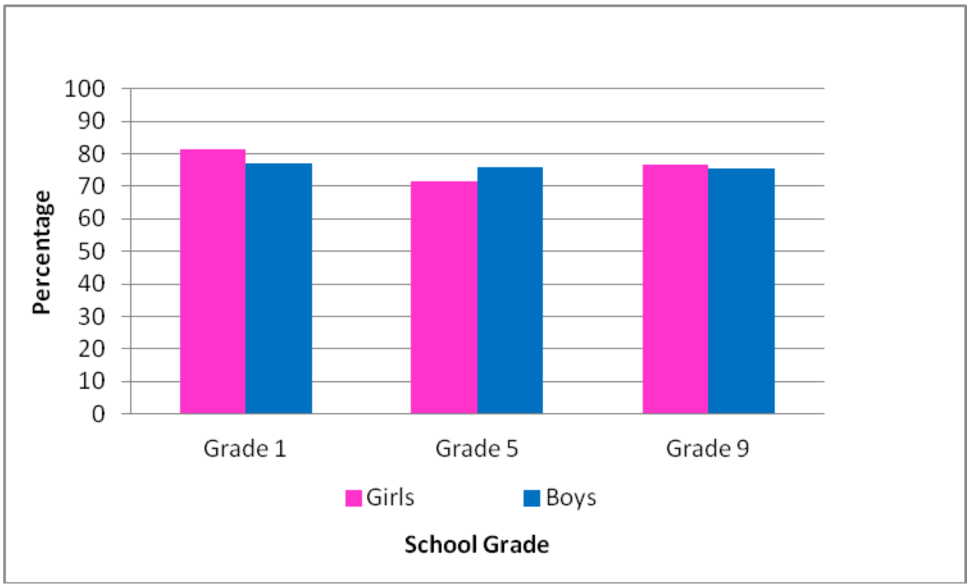

Figure 7-7 Home ownership of TV for study participants by grade and gender

Location of TV watching (Figures 7-8 and 7-9)

The majority of children also reported watching TV in their own home, as opposed to in someone else's home; this figure was slightly lower for boys than for girls.

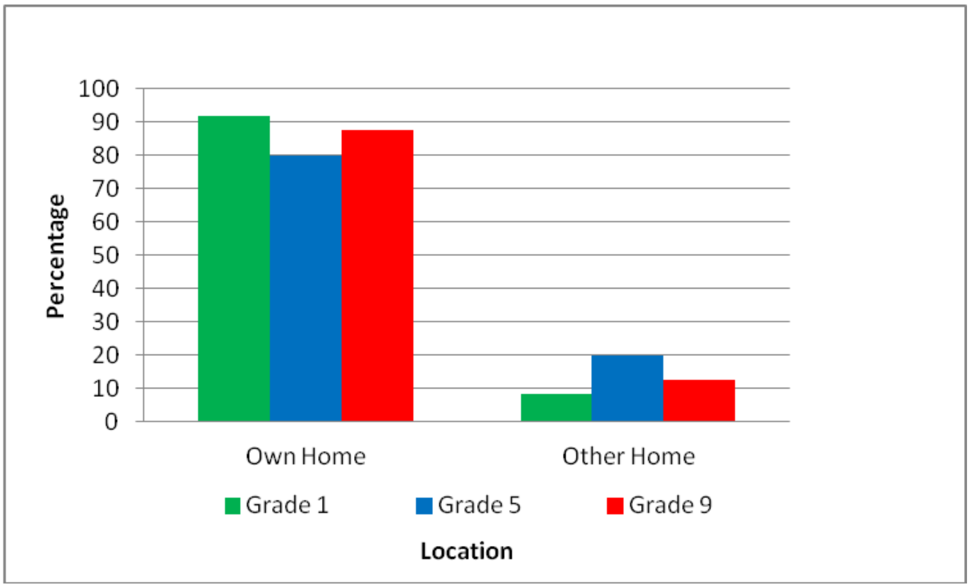

Figure 7-8 Location of TV watching by study participants (girls)

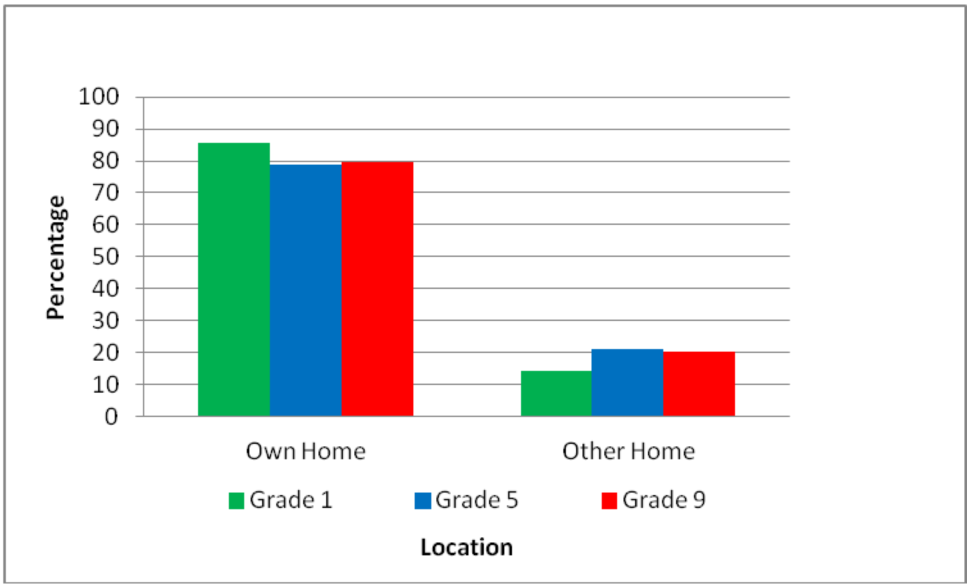

Figure 7-9 Location of TV watching by study participants (boys)

Duration of TV watching per day (Table 7-1)

Reported length of time spent watching TV was lowest in grade 5 and highest in grade 9, with grade 9 individuals reporting an average of over 2 hours viewing time per day.

Participation in sport (Figure 7-10)

Sports participation was defined as participation in an organised sport such as football, netball etc or in any unofficial playground game. Sports participation varied across the grades and was lower in girls than boys at all age points and lowest in grade 9 girls (<30%).The highest participation for each sex was reported by grade 5 subjects.

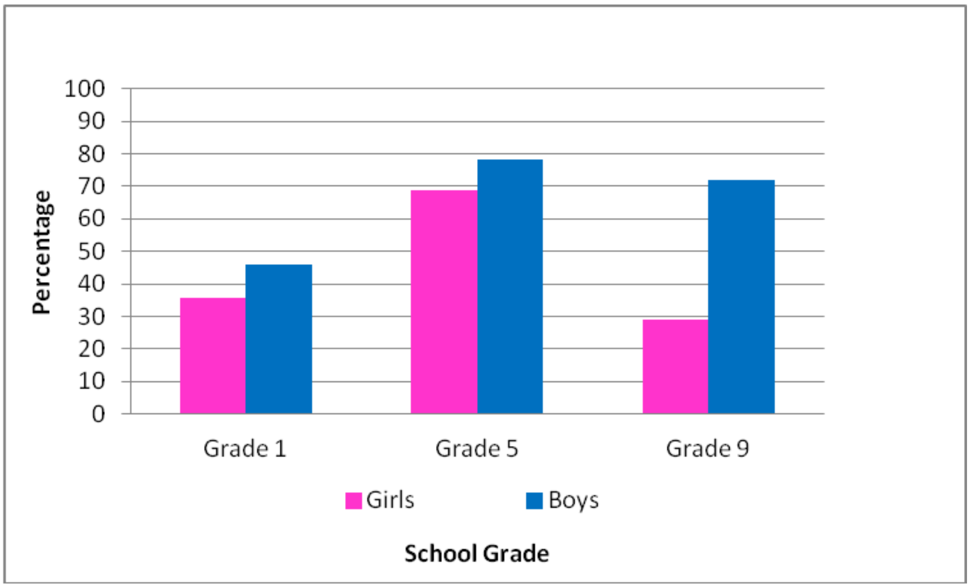

Figure 7-10 Sports participation of study participants by grade and gender

In summary, the participants in this sample displayed high proportions of water collection (68 - 90%) and high levels of active commuting to school (72 - 97%). The levels of TV ownership and watching were higher than might be expected for a rural sample in South Africa (70 - 80%) and related closely to those reporting having electricity at home. With regards to sports participation levels varied across the grades and were lower in girls than boys at all age points and particularly low in girls in grade 9 (<30%). Due to the high number of different sports reported a detailed analysis of the specific sports played by individuals was beyond the scope of this thesis however in general the most common organised sport among boys was football and among girls was netball, although the majority of individuals chose the ‘other’ option and listed a local/playground game as the sport which they played.

Table 7-1 Results of lifestyle questionnaire administered to study participants

Variable	Grade 1		Grade 5		Grade 9	
	Male	**Female**	**Male**	**Female**	**Male**	**Female**
Total (n)	264	250	234	269	182	320
Water collection n (%)	231 (88)	225 (90)	199 (85)	235 (87)	124 (68)	254 (79)
Time to collect water one way mins Mean (SD)	21 (12)	24 (13)	23 (16)	23 (15)	19 (21)	28 (28)
Walk to School n (%)	196 (75)	181 (72)	226 (97)	247 (92)	161 (89)	256 (81)
Journey time to school one way mins Mean (SD)	30 (14)	30 (13)	32 (17)	29 (16)	36 (24)	39 (25)
Electricity at home n (%)	209 (79)	203 (81)	164 (70)	194 (72)	140 (77)	243 (76)
Watch TV n (%)	204 (77)	204 (82)	178 (76)	193 (72)	137 (76)	245 (77)
TV hours daily Mean (SD)	1.8 (0.9)	1.7 (0.9)	1.6 (0.7)	1.5 (0.7)	2.3 (1.4)	2.3 (1.5)
Sport participation n (%)	121 (46)	89 (36)	183 (78)	185 (69)	131 (72)	93 (29)

7.1.1 Discussion of lifestyle data

Main findings of lifestyle assessment by questionnaire

The results of this lifestyle questionnaire showed a population with a high prevalence of water collection (70 - 90%) and active commuting (70 - almost 100%). Prevalence of TV watching was also higher than might be expected (70 - 80%) and this was closely correlated to availability of electricity at home.

Levels of sport participation varied but were lower in girls than boys at each age group and were very low in grade 9 girls (<30%).

Implications

It appears from these findings that physical activity is most commonly undertaken while carrying out essential household tasks and other daily necessities such as water collection and walking to school, whereas leisure time activity is more likely to be spent watching TV than participating in sport. Few data exist on sport participation in children and adolescents and this prevents comparison of data in the present study with other studies, however, participation appears low, particularly in girls in the older age group and this may play an important part in the increased prevalence of overweight and obesity within this group and may be a point to consider when planning any future interventions.

Comparison of lifestyle assessment in present study with other studies

Traditionally, water collection is a task predominantly carried out by women, with a United Nations Survey having reported that of 177 countries surveyed (both developed and developing) women spent a total of 40 billion hours collecting water annually (UNDP, 2006). Interestingly, in the present sample water collection appears to be a task not just carried out by girls; a high proportion of both boys and girls in the sample reported collecting water. There is evidence suggesting that after women, young children are the next most common group to be assigned the task of water collection (WHO/UNICEF, 2010). In the present study, there is a trend for water collection to be lower in the older age groups but for levels to be higher in girls compared to boys at each age group. Where collecting water for the household is a task unheard of in the majority of developed countries, it remains a common household task for individuals living in developing countries and therefore in turn it may contribute significantly to overall physical activity, as well as having an effect on weight status (Tharenos and Santorino, 2009, Prista et al., 2009). For this reason it is crucial that a population's level of development is taken into account when developing or implementing interventions.

Levels of active commuting (defined as walking or cycling) to school are high in this sample when compared to other western samples which have shown a significant decline in recent years (Lee et al., 2008, Merom et al., 2006, Metcalf et al., 2004). A national household survey of all children in the United States, found a decline of active commuting from 50% to 12% over the past 30 - 40 years and suggests this is a potentially important aspect for physical activity promotion (Lee et al., 2008, Tudor-Locke et al., 2001). Similar declines have also been noted in both Australia (Merom et al., 2006) and the UK (Metcalf et al., 2004, Black et al., 2001). The majority of existing data on active commuting has been collected from children living in developed countries (Lee et al., 2008) and there are no comparable studies of active commuting prevalence in South Africa. In the present study, the levels of children actively commuting to school is slightly lower in grades 1 and 9 compared to grade 5; a possible reason is that parents often opt for young children to be transported to school for safety reasons (Johansson et al., 2012). In some countries 'walk to school' initiatives such as the "walking school bus" have been put in place to try and combat this issue and provide a safe means for children to walk to school themselves, while also providing a physically active alternative to travelling by car or bus (Mendoza et al., 2011a). The reason for slightly lower levels of active commuting in grade 9 learners compared to grade 5 learners in the present study may be that grade 9 learners often have further to travel to get to their secondary school and so for practical reasons often choose to travel by motor vehicle rather than to walk. The longer distances travelled by grade 9 pupils may also explain why the time taken to travel to school in this age group is longer when compared to the two younger age groups. In a study of 4,013 schoolchildren aged 15 - 17 years in Ireland it was found that 2.5 miles was considered the achievable limit for active commuting (including both walking and cycling) with each additional 1 mile increase in distance leading to decreased odds of active commuting of 71% (Nelson et al., 2008). It is unclear what distance would generally be considered "too far" in this rural south African population and further qualitative work may be beneficial. A recent systematic review found there was an association between active commuting and overall physical activity levels, however, the association of active commuting with BMI and overweight status was less clear and more research is warranted in this area. The review also suggested that active commuting may not be a strong enough intervention to implement change on its own, however, when coupled with other lifestyle changes it may have a significant effect (Lee et al., 2008).

Access to electricity and reported television watching are closely correlated in the present sample; this is interesting as it suggests that despite the rural location, televisions are seen as an essential asset for those with electricity. Overall, access to electricity in sub-saharan Africa was 17% of households in 2002, however Mauritius, South Africa and Zimbabwe displayed levels of access well above the other sub-saharan countries

(Davidson, 2004). In recent years increasing electricity access has been a primary objective in South Africa with the South Africa national electrification programme running from 1994-1999 and aiming to increase access to 66% of households by 2001 and the Energy White Paper being released in 1998 with the main objective being to achieve universal household access to electricity by 2012 - with a specific priority for the poor (Department of Minerals and Energy, 1998). Where South Africa was found to have 36% access in 1993 (Borchers, 2001) it was reported that 64% of homes were electrified by 2007. As the initial target of universal access (100%) by 2012 was not achieved the target has now been changed to 2019 (Department of Minerals and Energy, 1998). It is estimated that approximately 80% of households should have access by 2013 and thereafter targets and funding will need to be reassessed. Within the Africa Centre DSA, access to electricity rose from 50% to 62% in the period from 2001 to 2006 (Tanser et al., 2008). Results of the Statistics South Africa consumer survey 2007 found national television ownership rose from 53.8% in 2001 to 65.6% in 2007 (StatsSA, 2007). While increasing electrification is a positive goal, the association of an increase in TV ownership, while also positive and an indication of development, has the potential to increase time spent sedentary and in turn possibly decrease total physical activity, as may have been the case in western countries. There is ongoing debate as to whether sedentary activity does displace physical activity (Biddle et al., 2004a, Fountaine, 2011) and this is a trend which should be monitored.

Interestingly sports participation appeared to be inversely associated with TV watching in grade 5 participants in that they appeared to watch less TV (spend less time sedentary) and play more sport (spend more time active). On the contrary, in grade 9 a similar percentage of both boys and girls reported watching TV (approximately 75%) and for a similar time per day (2.3 hours) yet sports participation was very different between the sexes with over 70% of boys reporting participation in sport and only 29% of girls. As was discussed in ‘Chapter 1: Introduction’ unfortunately physical education does not now feature in the South African school curriculum (Marshall and Hardman, 2000). Given the rural location of the present sample, low levels of dispensable household income and limited access to sports equipment and facilities, as well as a lack of physical education in schools may severely disadvantage these rural children and essentially remove all accessibility to sport. Girls appear to report lower levels of participation than boys at all age groups and most noticeably so in the oldest age group (grade 9). This is consistent with existing literature from western countries where girls' participation in organised sport during and post puberty has been shown to decrease (Baker et al., 2007, Davison et al., 2007, Kimm et al., 2002). This may be for a variety of reasons and could be a very important target group for any future physical activity interventions.

Strengths and weaknesses of lifestyle assessment conducted in present study

This is the first study of its kind to be conducted within this rural area of South Africa and the findings from the present sample provide data which will be useful to inform future interventions. This questionnaire had not been pre-validated, however, it was developed taking into consideration the present study setting and other questionnaires which had been carried out in similar rural, African settings (Prista et al., 2000, Prista et al., 2009).

The same fieldworker conducted all questionnaire interviews, therefore eliminating the risk of inter-individual variation.

It may be valuable for this questionnaire to be repeated every 5 - 10 years to provide information on longitudinal trends within this population.

Chapter 8 Section 8.2 looks at the association between reported lifestyle and weight status/body fat in the present sample.

7.2 Results of the sub-sample study investigating physical activity assessed by accelerometry and dietary energy intake assessed by 24 hour dietary recall

This section includes results of data collected from the randomly selected sub-sample of participants from which physical activity and dietary intake data were collected (by accelerometry and 24 hour dietary recall respectively). The aims of this study were to assess the feasibility of conducting such a study in this population and also to allow exploratory analysis of data collected.

Of the 150 randomly selected participants invited to take part in the study, 112 (74%) participated in the physical activity assessment (of which data from 89 (59%) were of a standard considered useable) and 117 (78%) participated in the dietary assessment. Recruitment of participants in grade 1 was affected by national school strikes (see Chapter 5: Prevalence for a more detailed description), however, as the sub-sample study for the grade 1 children was conducted in homes with the aid of a parent or guardian, every effort was made to locate each child who had already provided consent prior to the strike action.

Table 7-2 Overall recruitment of sub-sample participants

	Physical activity n (%)			**Diet n (%)**		
Randomly selected	150			150		
Participation	112 (75%)			117 (78%)		
Useable data	89*(59%)			117 (78%)		
School grade	**Total**	Boys	Girls	**Total**	Boys	Girls
1	**26**	15	11	**30**	16	14
5	**33**	19	14	**42**	20	22
9	**30**	13	17	**45**	18	27

*Useable = provided a minimum of at least 3 days with at least 6 hours per day (Penpraze, 2006)

7.2.1 Physical activity

Table 7-3 Consent, participation rates and final useable accelerometer data by grade

	Grade 1 (Age 7 years)	Grade 5 (Age 11 years)	Grade 9 (Age 15 years)
Randomly selected	**50**	**50**	**50**
Consent refused/absent from school	19	10	9
Consented	**31 (62%)**	**40 (80%)**	**41 (82%)**
Accelerometer did not work	2	1	1
Accelerometer lost	1	1	1
Data not useable	2	5	9
Final	**26 (52%)**	**33 (66%)**	**30 (60%)**

Of the total sample selected, 112 (75%) consented to taking part, of those data from 4 (3.6%) accelerometers could not be used due to technical problems with the accelerometer, 3 (2.7%) accelerometers were never returned despite several attempts to retrieve them and 16 (14.3%) accelerometers did not contain sufficient data; classified as at least 3 days with at least 6 hours per day. It must be taken into consideration that the grade 1 sample was affected by national strikes (explained in Chapter 5: Prevalence) and therefore a true comparison cannot be made between consent rates from the three different age groups.

7.2.1.1 Results of accelerometry data for sub-sample

Accelerometry wear time per day

The majority of participants wore their monitor for at least 6 out of the 7 days and for a median of 12 - 13 hours per day. Males in grade 9 wore the monitor for the shortest time each day median (IQR) 12.3 (10.9-13.8) hours and females in grade 5 for the longest 13.3 (12.7-13.9) hours (Table 7-4). However, with all age groups and both sexes the typical wear time was much longer than the minimum of at least 3 days, with at least 6 hours per day required for stable measures of physical activity (Penpraze, 2006, Trost et al., 2005, Basterfield et al., 2011b)

Total volume of physical activity (assessed by counts per minute)

Total volume of physical activity was lower in the older than in the younger age groups, as shown by lower results for both single and integrated counts per minute (cpm). Volume was generally higher in males than females in each age group.

Intensity of physical activity and time spent in sedentary behaviour

The percentage of time (% time) spent sedentary was higher in the older compared to the younger age groups and was significantly higher in females than males at grade 5, however did not reach significance between males and females in grades 1 or 9. Both % time spent in light intensity activity and % time spent in moderate - vigorous physical activity (MVPA) were significantly lower in the older compared to the younger age groups and were slightly lower in females than males at each age point, although this did not reach significance except for light intensity physical activity results in grade 5 (Table 7-5).

Table 7-4 Total wear time and volume of activity

Median(IQR)	Grade 1 (7 years)		Grade 5 (11 years)		Grade 9 (15 years)	
Sex	Male	Female	Male	Female	Male	Female
Total (N)	15	11	19	14	13	17
Days	6 (5-7)	7 (6-7)	6 (5-7)	7 (4-7)	6 (4-7)	6 (4-7)
Total hours	82.7 (66-89)	82.1 (79-94)	83.1 (63-90)	89.3 (50-96)	79.5 (52-86)	70.3 (50-95)
Hours per day	12.7 (12.0-13.1)	13.1 (12.4-13.4)	12.9 (12.4-14.0)	13.3 (12.7-13.9)	12.3 (10.9-13.8)	12.9 (11.3-14.0)
Single counts per minute	1017 (835-1191)	874 (849-1206)	796 (695-872)	613 (583-777)	666 (399-776)	485 (401-537)
Integrated counts per minute	1794 (1598-2096)	1661 (1463-1988)	1523 (1380-1672)	1257 (1067-1418)	1328 (1045-1529)	989 (813-1269)

7.2.1.2 Analysis of intensity of physical activity using cut points (Puyau and Evenson)

There are a number of different cut points available for assessing counts per minute and how this relates to intensity of activity. Use of different cut points potentially affects classification of different exercise intensities and therefore proportion achieving physical activity recommendations. A recent review by Trost et al compared different cut points and concluded that the Evenson cut points were the most appropriate to be used to analyse accelerometer data in youth (Trost et al., 2010). Prior to this review being published it had already been decided to use Puyau cut points in the present study, however, given the new evidence for use of Evenson cut points it was decided these would also be used allowing comparison to previous studies which had used Puyau cut points, as well as a comparison between the two different cut points (Tables 7-5, 7-6 and 7-7).

Table 7-5 Intensity of physical activity and sedentary time using Puyau cut points

Median (IQR)	Grade 1 (7 years)		Grade 5 (11 years)		Grade 9 (15 years)	
Sex	Male	Female	Male	Female	Male	Female
Total (N)	15	11	19	14	13	17
% Time Sedentary/ day	51 (45 - 57)	56 (44 - 60)	61 (55 - 68)	71* (63 - 75)	66 (60 - 82)	76 (72 - 80)
% Time Light Activity/day	46 (43 - 53)	43 (38 - 51)	37 (31 - 42)	28* (24 - 34)	33 (17 - 38)	24 (19 - 27)
% Time **MVPA /day	1.7 (1.2 - 3.6)	1.5 (1 - 4.6)	1.3 (0.8 - 1.8)	0.9 (0.4 - 1.3)	0.6 (0.2 - 1.4)	0.2 (0.1 - 0.8)
Minutes **MVPA per day	**12**	**11**	**10**	**6**	**4**	**1**

**MVPA = moderate - vigorous intensity physical activity
*Significantly different to male ($p<0.05$)

Table 7-6 Intensity of physical activity and sedentary time using Evenson cut points

Med(IQR)	Grade 1 (7 years)		Grade 5 (11 years)		Grade 9 (15 years)	
Sex	Male	Female	Male	Female	Male	Female
Total (N)	15	11	19	14	13	17
% Time Sedentary/ day	13.8 (12-18)	13.5 (12-15)	26 (23-67)	23.3 (20-28)	32 (25-42)	40.8 (36-44)
% time Light activity/day	76.4 (75-80)	80.0 (75-82)	69.8 (67-72)	73.7 (69-75)	62.6 (57-70)	56.9 (53-63)
% time *MVPA /day	7.7 (5.5-10.6)	6.0 (4.7-13.4)	5.8 (3.9-6.6)	3.2 (2.2-4.9)	3.1 (1.2-5.4)	1.4 (0.28-2.5)
Minutes *MVPA per day	**59**	**47**	**45**	**25**	**23**	**11**

*MVPA = moderate - vigorous intensity physical activity

7.2.1.3 Comparison of different cut points Evenson vs Puyau

Table 7-7 Comparison of MVPA levels using two different accelerometer cut points (Evenson and Puyau)

	School grade 1		School grade 5		School grade 9	
	Puyau	Evenson	Puyau	Evenson	Puyau	Evenson
n	26		33		30	
Mean % MVPA	1.6	8.0*	1.5	5.1*	0.8	2.8*
Mean MVPA mins/day	17	61*	11	39*	5	20*
*Significantly different to Puyau in same grade p<0.01						

Levels of MVPA were significantly higher using the Evenson cut points, as opposed to those of Puyau, however, compliance with international recommendations for physical activity (60 minutes of MVPA on majority of days monitored) was low irrespective of the cut point used. In the present sample participants were considered to have met recommendations if they achieved at least 60 minutes of MVPA on the majority of days monitored. Applying Puyau cut points, no participants met the recommendations of at least 60 minutes MVPA per day, however, for Evenson cut points 7 learners (27%) in grade 1 and 2 (6%) in grade 5 met the recommendations but 0 (0%) in grade 9.

Using the Puyau accelerometry cut points (Puyau et al., 2002), mean time spent in MVPA in the South African children and adolescents was low, in boys 1.7% of waking hours (12 mins/day) at age 7, 1.3% (10 mins/day) at age 11 and 0.6% (4mins/day) at age 15. In girls 1.5% of waking hours (11 mins/day) at age 7, 0.9% (6 mins/day) at age 11 and 0.2% (1 mins/day) at age 15. If the definition of 'sufficiently active' was achieving at least 60 minutes of MVPA on most days (DoH, 2011, Strong et al., 2005, WHO, 2010, CSEP, 2011) then *no* participants achieved this level of activity. This apparently low level of MVPA was not a function of the choice of accelerometry cut point chosen to measure MVPA. If the alternative Evenson et al accelerometry cut point was used (Trost et al., 2010) the mean minutes of MVPA per day were, in boys, 8.3% of waking hours (63 mins/day) at age 7, 6.3% (50 mins/day) at age 11 and 3.7% (28 mins/day) at age 15. In girls 7.6% of waking hours (59 mins/day) at age 7, 3.3% (25 mins/day) at age 11 and 2.1% (15.6 mins/day) at age 15. Only 27% (7), 6.1% (2), and 0% (0) of participants in each age group 7, 11 and 15 respectively, were 'sufficiently active' if the Evenson cut point was applied.

7.2.1.4 Discussion

Main findings of physical activity assessment by accelerometry

Children and adolescents in the present study were characterised by a relatively high volume of physical activity: the total amount of time spent in light intensity physical activity and the accelerometer count per minute were both much higher than in directly comparable samples from the western world (Basterfield et al., 2011a). However, this high volume of physical activity was carried out at relatively low intensity. The samples were comparable in that they included subjects of the same age as in the present study and also used the same accelerometer cut points (Puyau); this comparison is discussed in more detail below.

As yet there is no gold standard for which cut point is most accurate in the analysis of accelerometry data, although a review was published recently (Trost et al., 2010) comparing several cut points currently in use and concluded that the Evenson cut points should be used to analyse accelerometer data in children and adolescents (study sample aged 5-15 years)(Trost et al., 2010). In the present study a comparison was made between two different accelerometry cut points, Puyau and Evenson, (see section 7.2.1.4 and table 7-7). The results of this comparison showed that there was a significant difference in results between the two cut points, with a higher percentage of individuals achieving daily recommendations using the Evenson cut point. Despite the difference in results between references, both methods revealed low compliance with international recommendations of 60 minutes MVPA per day.

Implications

The present study creates a difficulty of interpretation; was the sample sufficiently physically active or not? Time spent in light intensity physical activity was high, however, time spent in MVPA was low. Therefore, since only a minority of study participants met the international guidelines for MVPA it should presumably be concluded that the sample was not sufficiently active? The health benefits of relatively large volumes of light intensity physical activity have not been established for children and adolescents and future studies should focus on establishing whether the lifestyle described here for rural South African children and adolescents is widespread in other populations globally. If the lifestyle of high volume, low intensity physical activity is common globally this should perhaps stimulate future research on the health benefits of light intensity physical activity.

Comparison of physical activity data with other studies

One concern of the present study was that it would not be feasible to carry out accelerometry within this rural population. It was expected that the accelerometers would not be well accepted and that participation rates would be low, with many accelerometers never being returned. Although several individuals did initially question what the accelerometers were measuring and enquired whether they contained cameras or other recording devices, children and adolescents generally accepted them well and no major concerns were raised. When comparing the results of the present study to that of a previous feasibility study (Van Coevering et al., 2005), carried out in young adolescents in a western setting, results were not very different. Unuseable data due to mechanical/non technical problems was 8.5% in the study by Van Coevering et al vs 3.6% in the present study, accelerometers which contained sufficient useable data to be included for analysis were 92% vs 80% in present study and 1 (0.4%) student lost a monitor vs 3 (2.7%) in the present study(Van Coevering et al., 2005). Despite a slightly lower percentage of useable data, possibly as a result of individuals forgetting to wear the monitor, and higher percentage of lost accelerometers in the present study the results suggest that use of accelerometry is relatively feasible in the present population. To our knowledge only two other studies in sub-saharan Africa have measured physical activity by accelerometry, however neither study presented results regarding feasibility and therefore comparisons cannot be made to the present study (Prista et al., 2009, Ojiambo et al., 2012).

There are no directly comparable South African studies which have used accelerometry to measure child and adolescent physical activity. A recent study in Kenyan schoolchildren (Ojiambo et al., 2012) compared the levels of Actigraph-measured MVPA between rural and urban adolescents (mean age 14 years) and found rural adolescents engaged in significantly more minutes of MVPA per day than the urban children. The participants in the Kenyan sample were from an area of Kenya home to the Nandi tribe; these individuals live at a relatively high altitude and are known as the ‘runners’, therefore may not be representative of the general Kenyan population. However, comparing the Kenyan data to the present sample, the minutes spent in MVPA were generally higher in both the rural and urban Kenyan adolescents than in the participants from the present sample (the average Kenyan MVPA was 54 minutes or 7% of the day). Although the accelerometry cut points used in the Kenyan sample and the present study were the same (Puyau) a direct comparison of the results cannot be made as a different model of Actigraph (Actitrainer) was used, but it would appear that the South African participants in the present study had much lower MVPA than the Kenyan adolescents in the study by Ojiambo et al.

To the best of our knowledge, the only other accelerometry study which has taken place in children or adolescents in sub-saharan Africa was a study carried out in Mozambique (Prista et al., 2009) which used accelerometry to measure physical activity of rural children. Findings were similar to those from the present study in that boys displayed significantly higher levels of physical activity than girls and in this cross-sectional study physical activity appeared to be lower amongst the older age groups. Prista et al compared the Mozambican sample to a Portuguese sample to allow assessment of the difference in physical activity between children in developed and developing countries, and found that the Mozambicans had a significantly higher total volume of physical activity but took part in less minutes at a higher intensity of physical activity than the Portuguese participants. Data in this study were analysed using different methods to those in the present study (activity was measured in number of bouts at specific intensities and moderate - vigorous intensity physical activity was further split into moderate physical activity, vigorous physical activity and very vigorous physical activity and counts were presented per day rather than per minute) and therefore results could not be directly compared.

As indicated above, accelerometry can be analysed in different ways (number of bouts at different intensities, % of total time at a specific intensity etc) and using different cut points. Apparent levels of physical activity vary systematically dependent on which accelerometer method is used (Reilly et al., 2008, Trost et al., 2010, Basterfield et al., 2011a), thus to compare data from the present study with those from a western sample that used identical methods, accelerometers and accelerometer cut points I have used a recent study of a socio-economically representative sample of English children (Basterfield et al., 2011a), with age-matched comparison data to the South African sample of 7 year olds (Fig1a,1b,1c) . The 7 year olds in England spent significantly more daily time in MVPA than the South Africans, at 3.8% of time, or around 26 mins/day versus 1.6% of time, around 12 mins/day (Basterfield et al., 2011a) (Fig 1a). However, comparison of mean MVPA between South African and English children does not do justice to the differences in physical activity between the two samples. Despite lower MVPA, the South African children were substantially and significantly more physically active (total volume of physical activity; Fig 1c), typically spending around 5.5 hours per day in light intensity physical activity compared to 2 hours in the English children. Moreover, time spent sedentary was much lower in the South African children than in the English children, and adverse effects of sedentary behaviour are now well-established (Tremblay et al., 2011, Tremblay et al., 2010).

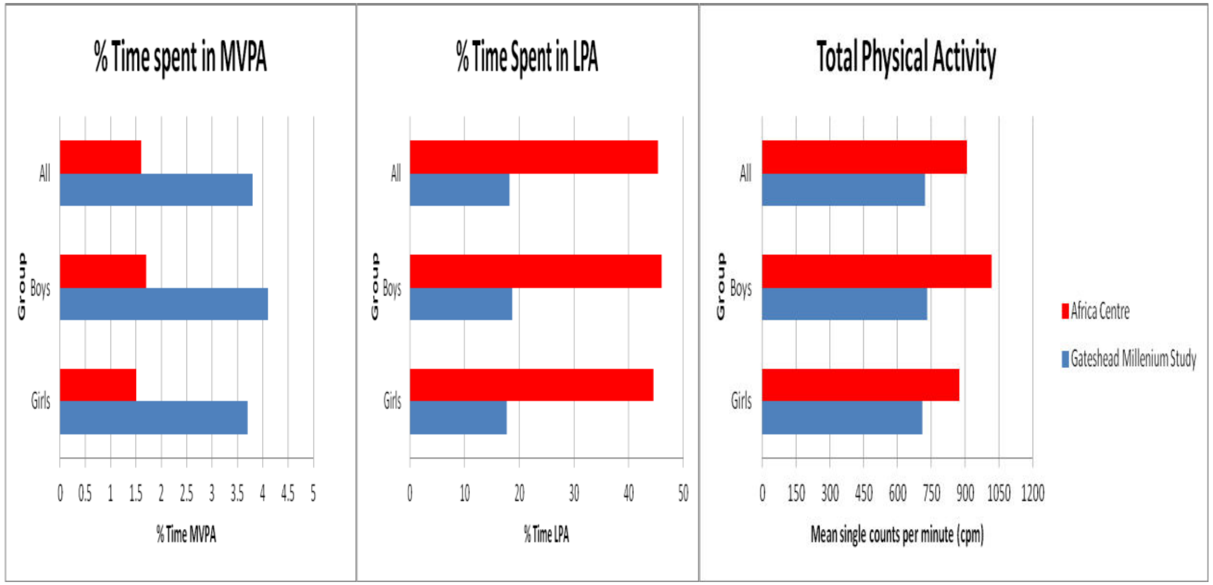

Figure 7-11 Comparison of physical activity between English and South African 7 year olds
Footnotes: MVPA moderate-vigorous intensity physical activity; LPA Light Intensity Physical Activity. Africa Centre data from present study; Gateshead Millennium Study data from Basterfield et al(Basterfield et al., 2011a).

Comparing the data from the 15 year olds in the South African sample to a recent US national survey of 12-15 year olds (Troiano et al., 2008) total volume of physical activity (accelerometer cpm) in the US was substantially lower; supporting the view that the South African sample was characterised by a high volume of physical activity. Even the adolescents (age 15 years) in the South African sample had higher total volume of physical activity than the English children (age 7 years) in the Gateshead Millennium Study, despite the fact that physical activity declines markedly through childhood and adolescence (Basterfield et al., 2011a, Kimm et al., 2002). In summary, the South African children and adolescents had very high levels of physical activity, yet would fail to meet international physical activity guidelines.

Physical inactivity is known to increase risk of many non-communicable diseases such as coronary heart disease, type 2 diabetes and some cancers: it is estimated to have been the primary cause of around 5.3 million deaths in 2008; equating to approximately 9% of the total 57 million deaths globally (Lee et al., 2012). There is increasing awareness of the importance of physical activity for the current and future health of school-age children and adolescents (Janssen and Leblanc, 2010), manifested in public health recommendations (DoH, 2011, Strong et al., 2005, WHO, 2010, CSEP, 2011). These recommendations are based on evidence obtained largely from children and adolescents in the developed world. Recommendations for school-age children and adolescents have focused on moderate - vigorous intensity physical activity (MVPA), the construct best represented in the evidence. At least 60 minutes MVPA per day is recommended (DoH, 2011, Strong et al., 2005, WHO, 2010, CSEP, 2011), and this is used widely as the basis of public health surveillance. However, a recent paper published in the Lancet physical activity series found that 80.3% of 13-15 year olds fail to meet these recommendations and in general boys are more active than girls (Hallal et al., 2012). Evidence-based recommendations focussed on total volume of physical activity or on light intensity physical activity have not been possible due to lack of evidence on the relationship between these dimensions of physical activity and health.

Strengths and weaknesses of physical activity assessment in present study

There is a lack of objective physical activity data from individuals in developing countries and more specifically in sub-saharan Africa. This study adds to the evidence base of data available and therefore will be useful for informing future interventions in this area, as well as for studies investigating secular trends.

The present study confirms that studies of this nature are feasible within this population and, despite a small number still choosing not to take part in accelerometry, the technique was widely accepted by the majority of participants. Although the analysis for this study is mainly exploratory, the sample includes participants from three different age groups and both sexes, therefore allowing preliminary analysis of age- and gender-related differences. The same fieldworker collected all data and therefore there is low risk of inter-individual variation in collection procedures (see Chapter 4: Methods).

One of the benefits of objective measurement of physical activity is that it allows attribution of health effects to different dimensions of physical activity with greater confidence, in cohort and intervention studies (Reilly et al., 2008, Janz et al., 2008). For example, in the Avon Longitudinal Study of Parents and Children (ALSPAC) cohort in England, variation in MVPA was the dimension of physical activity which most influenced body fatness (Riddoch et al., 2009, Ness et al., 2007), but in the same sample at the same age it was variation in total volume of physical activity, not MVPA, which had greatest impact on blood pressure (Leary et al., 2008). Ongoing and completed cohort studies with objective measures of physical activity are valuable sources of evidence on relationships between all dimensions of physical activity and health.

Although accelerometers are a well validated technique for objective measurement of physical activity (De Vries et al., 2009, de Vries et al., 2006) there is a possibility that total energy expenditure may have been underestimated in the present study as the use of accelerometers to measure common household tasks which take place in many rural areas (e.g., pounding cereals, carrying water) has not been validated. This is because accelerometers do not account for the extra energy expended with load bearing exercises and also because they are most commonly worn on the hip and may not accurately record the energy expenditure of tasks performed predominantly by the upper limbs. Further, accelerometry does not capture information on type of activity, however, participants in the present study did have the option to complete a self-report activity log of activities carried out on each day the accelerometer was worn, although emphasis was put on wearing the accelerometer rather than worrying about filling in the activity log, as it was feared this added burden may lower participation (activity log information not presented here).

Although the present sample was found to be socio-economically representative of the local population the power is limited by its small sample size and further large scale studies are required.

Conclusions of physical activity assessment in present study

Children and adolescents with a high volume of physical activity carried out at relatively low intensity create a difficulty of interpretation for public health surveillance: are they sufficiently physically active or not? Our observations also pose a challenge to future physical activity recommendations: should these be framed solely in terms of MVPA in future? The extent to which the lifestyle described in the present study is a challenge will depend in part on how common it is among children and adolescents globally.

Evidence from studies using objective measures of habitual physical activity is almost non-existent in low - middle income countries. I therefore suggest first that future studies should focus on establishing whether the lifestyle described here for rural South African children and adolescents is widespread in other populations globally.

The present study also emphasises the importance of the lack of evidence on the health effects of variation in the total volume of physical activity, and the health effects of variation in light intensity physical activity, as the majority of reviews have been based on MVPA. Future research should therefore focus on testing for associations of total volume of physical activity and light intensity physical activity with health, and should do so in a range of populations.

There is a distinct lack of physical activity interventions in low income countries (Pratt et al., 2012). Future intervention studies are therefore warranted in this area and should consider findings from this study and their generalisability to other populations. Attention should also be paid to investigating whether changes in total volume of physical activity and/or light intensity physical activity could be used to explain changes in health outcomes, in order to provide evidence on the health impact of these constructs.

Chapter 8 section 8.3 looks at the association between physical activity and weight status/body fat in the present sample as an exploratory analysis.

7.2.2 Dietary intake

Participation rates in the sub-sample were shown previously in Table 7.2. Of the 150 participants selected to take part, 117 (78%) consented and provided 24 hour recall data on two occassions, at the beginning and end of their accelerometry measurements.

Participants of both sexes and at all ages appear to have a lower median energy intake than the recommended daily allowances (RDA, 1989)(see Figure 1-12) and UK estimated average requirements (SACN, 2011)(Table7-8); the difference between recommended and reported intake was more noticeable in the older age groups, especially in grade 9 males.

Table 7-8 Descriptives of energy intake

	Grade 1 (7 years)		Grade 5 (11 years)		Grade 9 (15 years)	
Sex	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
Total (N)	16	14	20	22	18	27
Energy kJ Median (IQR)	6640 (5965-7913)	6584 (4812-7841)	8247 (7062-9070)	7096 (5790-8099)	7208 (5000-9082)	7072 (5774-8355)
Energy kcal Median (IQR)	1586 (1425-1890)	1573 (1149-1873)	1970 (1687-2166)	1695 (1383-1935)	1722 (1194-2169)	1689 (1379-1996)
Energy kJ/kg/day Median (IQR)	277 (254 –373)	290 (241–347)	231 (199 –271)	177 (151 –215)	128 (84–170)	131 (110–162)
Estimated average requirement (EAR)* kj/kg/day	296	278	258	237	211	187

*Scientific Advisory Committee on Nutrition (SACN, UK) energy requirement data

Recommended Daily Allowance – Energy (RDA, 1989)

Child 7-11 8368kJ / 1999kcal

Male 11-15 10460kJ / 2498kcal Female 11-15 9205kJ / 2199kcal

Male 15-19 12552kJ / 2998kcal Female 15-19 9205kJ / 2199kcal

Figure 7-12 US recommended daily allowances for energy by age and gender

Although energy intake was the main focus of this study, intake of macronutrients is also shown in Table 7-9, in addition, levels of underreporting are investigated in section 7.2.2.1.

Recommended macronutrient intakes, as a percentage of energy, are approximately 50% carbohydrate, 15% protein and <35% fat (COMA, 1996). Based on these recommendations participants in the present sample were generally consuming diets with the recommended intakes of carbohydrate and fat, although protein intake appears to be at the lower end of the recommendations in all age groups and therefore it may be advisable for protein intake to increase slightly in line with current guidelines.

Table 7-9 Reported carbohydrate, protein and fat intake by total (g/day), as a percentage of energy intake (%) and weight adjusted (g/kg/day)

Median(IQR)	Grade 1 (7 years)		Grade 5 (11 years)		Grade 9 (15 years)	
Sex	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
Total (N)	16	14	20	22	18	27
CHO (g)	212 (172-245)	197 (157-246)	248 (208-280)	225 (191-267)	243 (184-324)	232 (186-256)
CHO (kcal)	848	788	992	900	972	928
Approx CHO %*	53.5	50.1	50.4	53.1	56.4	54.9
CHO (g/kg)	9.8 (7.0-11.9)	8.9 (8.1-10.5)	7.5 (6.8-8.3)	6.1 (5.0-7.2)	4.5 (2.9-6.2)	4.3 (3.3-5.0)
Protein (g)	41 (33-58)	40 (33-45)	45 (41-53)	41 (32-47)	41 (26-52)	41 (32-50)
Protein (kcal)	164	160	180	164	164	164
Approx protein %*	10.3	10.2	9.1	9.7	9.5	9.7
Protein (g/kg)	1.8 (1.5-2.4)	1.7 (1.4-2.2)	1.4 (1.2-1.6)	1.1 (0.8-1.4)	0.7 (0.5-1.3)	0.8 (0.6-1.0)
Fat (g)	54 (36-72)	49 (32-66)	70 (54-84)	56 (47-69)	51 (31-61)	60 (41-76)
Fat (kcal)	486	441	630	504	459	540
Approx fat %*	30.6	28.0	32.0	29.7	26.6	31.9
Fat (g/kg)	2.0 (1.6-3.6)	2.4 (1.5-3.0)	2.1 (1.5-2.6)	1.5 (1.3-1.8)	1.0 (0.5-1.4)	1.1 (0.8-1.4)

*Expressed as a % of median kcal shown in Table 7-8

7.2.2.1 Identifying underreporting or unphysiological intake

One of the biggest challenges facing dietary assessment is the accuracy of report by individuals (Fisher et al., 2000, Steyn et al., 2006). Collecting dietary data using direct observation or direct measures of intake are labour intensive, expensive procedures and therefore the majority of assessment relies on self-reporting by the individual themselves (Magarey et al., 2010). As in any scenario self-report carries the risk of inaccuracy in the context of diet, this may be for a wide variety of reasons such as inability of participants to report accurately due to lack of knowledge regarding foods eaten and preparation process, difficulty recalling intake, or being ashamed or too proud to report actual intake due to it being unhealthy, or the portion sizes or overall intake being too little or too much (Magarey et al., 2010).

Although it is not always possible to determine when an individual is reporting inaccurately, equations have been devised to try and capture the likelihood of a specific reported energy intake being unphysiological.

Firstly the Basal Metabolic Rate (BMR) of the individual must be calculated. For the purposes of this study BMR was calculated using by FAO/WHO/UNU equations (Joint FAO/WHO/UNU Expert Consultation on Energy and Protein Requirements, 1985). WHO/FAO/UNU has consistently been considered the most accurate for calculating the BMR of children and adolescents and has been used in many studies (Lanctot et al., 2008, Santos et al., 2010).

Table 7-10 Calculation of BMR using FAO/WHO/UNU equations

Age (years)	Males	Females
3-10	22.7 W +495	22.5 W+499
10-18	17.5 W +651	12.2 W+746
18-30	15.3 W + 679	14.7 W +496

(W being Weight in kg and output being in kcal).

After calculating BMR the discrepancy between reported energy intake and estimated energy expenditure must be considered in order to determine underreporting. To do this the estimated overall energy expenditure must be calculated and then subtracted from the reported energy intake, if the output is a negative value this would be suggestive of underreporting. 1.27xBMR is suggested as the lowest possible survival requirement for habitual energy intake by WHO/FAO/UNU (Joint FAO/WHO/UNU Expert Consultation on Energy and Protein Requirements, 1985)

Underreporting using WHO/FAO/UNU equation

In the present sample, it was found that 41.4% (48/116) had negative (i.e. unphysiological) values when energy expenditure was calculated as 1.27XBMR and subtracted from average reported energy intake from 2 x 24hour recalls, i.e., Energy Intake - (1.27xBMR). The 41.4% of participants with negative intake stratified by grade and gender is shown in Table 7-11. Underreporting (unphysiological intake) was highest in grade 9 subjects and higher in females than males at all age points.

Table 7-11 Underreporting using WHO/FAO/UNU equation (1.27 x BMR)

	Males	Females	All by grade
Grade 1	3/15 (20%)	4/14 (29%)	7/29 (24%)
Grade 5	4/21 (19%)	9/21 (43%)	13/42 (31%)
Grade 9	11/18 (61%)	17/27 (63%)	28/45 (62%)
All by Sex	18/54 (33%)	30/62 (48%)	

Underreporting using Goldberg equation

The Goldberg CUT OFF1 (Goldberg et al., 1991, Black, 2000) was also applied to the data from the present sample. This cut off is used to estimate whether the reported energy intake is a plausible measure of habitual intake, as opposed to whether the reported intake is plausible for that specific time period. A recent study investigating the validity of the Goldberg cut off in adults concluded that in the absence of data on objective energy expenditure the Goldberg cut off is a valid approach to determine underreporting (Tooze et al., 2012). The equation 1.35 X BMR was used, this is considered to be the minimum physical activity level associated with normal circumstances, Goldberg states that it is 'virtually inconceivable for people to live a normal life at less than 1.2 x BMR'. The prevalence of underreporting using this reference (Energy Intake -1.35 x BMR= -ve) is shown in (Table 7-12):

Table 7-12 Underreporting prevalence using Goldberg CUT OFF1 equation

	Males	Females	All
Grade 1	4/15 (27%)	5/14 (36%)	9/29 (31%)
Grade 5	9/21 (29%)	9/21 (43%)	15/42 (36%)
Grade 9	14/18 (78%)	18/27 (67%)	32/45 (71%)
All	24/54 (44%)	32/62 (52%)	

These figures demonstrate a marked increase in underreporting prevalence amongst the older age groups, seen in both sexes. Contrary to the results found when using the WHO/FAO/UNU equation, underreporting appeared higher in boys than girls at the oldest age group, however, similar results were found in the two younger age groups with underreporting higher in girls compared to boys.

The finding that boys show the highest levels of 'underreporting' at grade 9 is a surprising result given that underreporting is most commonly associated with girls, however, it does correspond to the results shown in this study where report of energy intake in grade 9 boys was well below recommendations and provides further evidence that underreporting is affected by age.

Another possible method of determining underreporting is to calculate energy intake as a % of predicted BMR; the results of this analysis are shown in Table 7-13. There is a clear decrease in energy intake as a % of predicted BMR in the oldest age group when compared to the youngest. Grade 9 males are the only ones with a lower quartile below 100%.

Table 7-13 Energy intake as % of predicted BMR

School Grade	Males	Females
1	145 (128 – 204)	161 (125 – 185)
5	158 (133 – 167)	136 (119 – 157)
9	101 (74.2 – 139)	119 (105 – 144)

Data expressed in % as Median (IQR)

Effect of weight status on underreporting

Eighteen of the 117 (approx 15%) participants in the dietary assessment were classified as overweight/obese using the WHO BMI-for-age reference (de Onis et al., 2007), 11 (61%) of whom were classified as under-reporters using WHO/FAO/UNU equation (Joint FAO/WHO/UNU Expert Consultation on Energy and Protein Requirements, 1985). Of those who were not classified as overweight/obese (99 participants) 37 (37%) were under-reporters. Of the 48 under-reporters identified using the WHO/FAO/UNU equation, 23% (11/48) were classified as overweight/obese.

Chapter 8 Section 8.3 looks further at an exploratory analysis of the association between dietary intake and weight status/body fat in the present sample.

7.2.2.2 Food consumption by total amount, frequency and food group

Although the main aim of the dietary assessment in this study was to look at the overall energy intake of the sample the dietary technique used also provided large amounts of data on food consumption and dietary habits and therefore an exploratory analysis of consumption of specific food items and food groups was also made in order to allow comparison with previous studies conducted in this area and throughout South Africa. The current South African dietary guidelines are shown in Table 7-14.

Table 7-14 Food Based Dietary Guidelines, South Africa

South African Food Based Dietary Guidelines (FBDGs)
1. Enjoy a variety of foods
2. Be active
3. Make starchy foods the basis of most meals
4. Eat plenty of vegetables and fruits everyday
5. Eat dry beans, peas, lentils and soy regularly
6. Chicken, fish, milk, meat or eggs could be eaten daily.
7. Eat fats sparingly
8. Use salt sparingly
9. Drink lots of clean, safe water
10. If you drink alcohol, drink sensibly
11. Use food and drinks containing sugar sparingly and not between

Most common foods consumed categorised by total amount (grams)

Phuthu (a traditional African dish made from maize meal, with a crumbly porridge-like texture) was the most commonly consumed foodstuff in terms of amount for participants in all age groups. Other starchy foods such as beans, white rice and white bread were also among the most common at all ages. No vegetables appeared in the top ten foodstuffs consumed and only minimal fruit (mainly in the form of fruit juice) and meat (beef curry, stewed pilchard) were reported. Tea appeared to be the main drink reported at all ages (see Table 7-15).

Table 7-15 Top ten food consumption by amount (grams) from 24 hour recall data collected on 2 occasions

	Grade 1		Grade 5		Grade 9	
Ranking	**Food**	**Total amount reported (g)**	**Food**	**Total amount reported (g)**	**Food**	**Total amount reported (g)**
1	Phuthu (All brands)*	12172	Phuthu (All brands)*	15048	Phuthu (All brands)*	15178
2	Sugar beans with oil & onion	6425	Rice, White, Cooked	9808	Tea, Brewed (Regular and Rooibos)	9130
3	Tea,Brewed (Regular and Rooibos)	5725	Sugar beans with oil & onion	8200	Rice, White, Cooked	6745
4	Rice, White, Cooked	4615	Tea, Brewed (Regular and Rooibos)	4340	Orange, Raw (peeled)	4900
5	Samp and Beans, 1:1	3313	Bread/Rolls, White	4320	Bread/Rolls, White	4530
6	Bread/Rolls, White	3096	Orange Juice, Fresh	3618	Sugar beans with oil & onion	4500
7	Maas / Sour Milk	2625	Coffee, Brewed/ Instant	3190	Coffee, Brewed/ Instant	4008
8	Orange Juice, Fresh	2500	Stewed pilchard	2845	Bread/Rolls, Brown	3570
9	Bread/Rolls, Brown	1770	Bread/Rolls, Brown	2640	Beef Curry	3150
10	Beef Curry	1470	Apple, Golden Delicious, Raw	2540	Orange Juice, Fresh	2625

*For grade 1 this included super white and ACE, grade 5 super white and special white and grade 9 super white, special white, ACE and induna. These different types of maize meal all contain slightly different fortification ingredients and different levels of milling e.g., ACE contains vitamins A, C and E and super white is more finely milled than special white.

Most common foods consumed categorised by frequency of consumption

When assessing consumption by frequency phuthu, white rice, beans and bread remained amongst the most common foods consumed (Table 7-16). However, several other foods which could be considered high in fat/sugar (often referred to as fast foods) also appeared in the top ten and there appeared to be a slight trend towards higher consumption of these foods in the older age groups. In grade 1, subjects reported consumption of sugar (n=30) and sweets (n=18), both foods high in sugar, but no high fat items appeared in the top ten. Grade 5 subjects reported both high fat and high sugar items with 33 reports of savoury snacks (niknaks, fritos) and 25 of sugar. However, grade 9 subjects had 4 high fat/sugar foods in the top ten with savoury snacks ranking as the second most commonly consumed food item (after phutu) with a total of 58 reports; sugar ranked 4th with 44, sweets and votkoek[1] ranked 8th and 10th with 37 and 34 reports respectively.

Table 7-16 Top ten food consumption by frequency from 24 hour recall data collected on 2 occasions

	Grade 1		Grade 5		Grade 9	
Ranking	**Food**	**Frequency of report (n)**	**Food**	**Frequency of report(n)**	**Food**	**Frequency of report(n)**
1	Phuthu	59	Rice, White, Cooked	77	Phuthu	71
2	Rice, White, Cooked	36	Phuthu	72	Snack, Savoury, eg., Niknaks, Fritos, Ghost Pops	58
3	Sugar beans with oil and onion	33	Chicken Stew	45	Rice, White, Cooked	47
4	Bread/Rolls, White	33	Sugar beans with oil and onion	41	Sugar, White, Granulated	44
5	Sugar, White, Granulated	30	Bread/rolls, White	41	Tea, Brewed	43
6	Tea, Brewed	29	Margarine, Polyunsaturated	40	Bread/rolls, White	40
7	Bread/Rolls, Brown	19	Snack, Savoury, eg., Niknaks, Fritos, Ghost Pops	33	Margarine, Polyunsaturated	37
8	Chicken stew	19	Bread/Rolls, Brown	27	Sweets, Hard Boiled/Soft Jelly	37
9	Sweets, Hard Boiled/Soft Jelly	18	Sugar, White, Granulated	25	Bread/Rolls, Brown	30
10	Margarine, Polyunsaturated	14	Milk Powder, Full Fat (Vit A, D & Iron added)	22	Vetkoek[1], Homemade (Cake Flour, Water)	24

[1]Vetkoek is a traditional South African food item consisting of dough deep fried in cooking oil, this is often filled with either a sweet or savoury filling or can also be eaten on its own.

Most commonly consumed food groups

A variety of food eaten appears to be higher amongst older age groups with average number of reported food items per subject increasing from 17 at grade 1 to 19 and 20 at grade 5 and 9 respectively.

Consumption of foods by food group is shown in table 7-17. Cereals were the most commonly reported food group. This may be considered in line with current recommendation to base meals on starchy foods, however, sugars, syrups and sweets, items which are advised to be eaten sparingly, were the second most frequently reported group in grade 1 and 9 and the 3rd most common in grade 5.

Consumption of fruit and vegetables was low and did not rank in the top 5 at any age group. Reported intake of fruit and vegetables was ranked lowest in grade 1 subjects.

Table 7-17 Top ten food consumption by food group

	Grade 1		Grade 5		Grade 9	
Rank	**Food**	**Frequency (n)**	**Food**	**Frequency (n)**	**Food**	**Frequency (n)**
1	Cereal and cereal products	205	Cereal and cereal products	305	Cereal and cereal products	303
2	Sugar, syrups, sweets	65	Meat and meat products	74	Sugars, syrups, sweets	129
3	Meat and meat products	48	Sugar, syrups, sweets	73	Miscellaneous	113
4	Legumes and legume products	40	Miscellaneous	62	Meat and meat products	84
5	Miscellaneous	38	Fats and oils	55	Fruit	73
6	Fats and oils	26	Legumes and legume products	50	Fats and oils	54
7	Milk and milk products	23	Fruit	45	Vegetables	48
8	Fruit	18	Vegetables	37	Milk and milk products	38
9	Vegetables	18	Milk and milk products	35	Legumes and legume products	37
10	Eggs	10	Fish and seafood	22	Beverages	13
11	Fish and seafood	6	Beverages	12	Fish and seafood	12
12	Beverages	1	Eggs	5	Eggs	8
13	Nuts and seeds	1	Sauces, seasonings and flavourings	3	Therapeutic/Special/Diet products	3
14	Sauces, seasonings and flavourings	1			Nuts and seeds	1
Total		500		778		916
Average items reported	Sample n=30	17	Sample n=42	19	Sample n=45	20

7.2.2.3 Discussion of dietary assessment

Main findings of dietary assessment in present study

Total energy intake appears to be below recommendations in all age groups and in both genders, however, macronutrient intakes, expressed as a percentage of total energy intake, were generally within recommendations. These results suggest that the general macronutrient composition of the diet is reasonably acceptable in terms of diet reported, however, the reported energy intake is below necessary levels.

A summary of underreporting prevalence carried out using different techniques shows that it is common in the present sample and that possibly explains the low energy intakes. However, it must also be taken into consideration that this is a low income rural setting where food security remains an issue and therefore it may be the case that some of the underreporting is genuine and periodic and therefore risk of undernutrition remains highly possible.

Findings of the present study appear to show that underreporting is higher amongst individuals who are classified as overweight/obese (approximately 60% of those overweight/obese were also classified as underreporters versus only 37% of those not overweight/obese) which strengthens the evidence suggesting that low intakes are indeed a result of underreporting as opposed to genuinely unphysiologically low intakes.

The finding that energy was being underreported by such large amounts was surprising and led to the suggestion that other nutrients were probably also being under-reported and therefore further detailed treatment of them was unlikely to be worth pursuing in great depth. Day-to-day variability in intake for both macro and micronutrient is likely to be much higher than for energy, which would result in measures of these over a 2 day period being less precise (Gibson, 2005).

When examining the specific foods being eaten it appears that many of the traditional foodstuffs remain popular in the diet such as phuthu, rice and beans, however, there is some evidence that differences are present between age groups with a possible increase in frequency of fast food consumption at older age groups with more frequent reporting of foods such as savoury snacks (niknaks etc.), voetkoek (“fat cakes”) and sweets (hard boiled/jelly) in the oldest age group. This may support the hypothesis that older children are eating more foods outside the home, have greater access to different foods and possibly higher consumption of fast or convenience foods. Consumption of fruit and vegetables also appears to be very low especially in the younger age groups.

Implications

It is unclear to what extent the apparently low energy intake in the present study is a result of underreporting or a function of genuinely low energy intake. An association was found between weight status and likelihood of underreporting (see section 7.2.2.1 in the present chapter and also Chapter 8 for more detailed information), this begs the question as to whether the underreporting is a result of the overweight present? Another possibility is that diet is not the main risk factor in the development of overweight and obesity but that in fact low levels of physical activity, high levels of sedentary behaviour and other higher level influences may have a more substantial effect.

The appearance of increased fast food consumption in the older age groups may be taken to indicate the potential presence of the nutrition transition in this area and the shift from a traditional African diet to a more westernised diet characterised by high fat, salt and sugar intake and low levels of fruit and vegetable consumption (Popkin, 2001, Popkin et al., 2012).

Comparison of dietary assessment data with other studies

Dietary assessment is consistently found to be problematic in that misreporting (either over- or under-reporting) is common especially amongst children and adolescents, therefore hampering the ability to accurately measure dietary intake (Magarey et al., 2010). Factors which have consistently been found to have an effect on misreporting are gender and weight status; with females and individuals of a higher weight status more likely to misreport (Magarey et al., 2010, Fisher et al., 2000). Other factors which have also been suggested as influential, but for which less evidence exists, are income, age, social desirability, smoking habits, physical activity level and participation in dietary restraint (Santos et al., 2010, Macdiarmid and Blundell, 1998). As described in section 7.2.2.1 above, in some cases misreporting may be due to genuine mistakes or inability to report correctly, however, in other cases it may be due to the embarrassment or guilt associated with reporting actual consumption. For this reason, foods which tend to be connected with a negative image such as those high in fat, salt, sugar (cakes, biscuits, crisps etc) are most commonly underreported, while those with a positive image such as fruit and vegetables are most commonly overreported (Kant and Graubard, 2003, Collins et al., 2010). Factors consistently known to hinder dietary assessment in children can include memory, attention span, knowledge and names of foods as well as preparation and cooking techniques (Livingstone and Robson, 2000).

Previous studies have recommended 24 hour dietary recall as a reliable and valid measure of energy intake to use within this age group (Burrows et al., 2010, Rankin et al., 2011a, Rankin et al., 2010), although it has also been suggested that accuracy of 24 hour recall may decline with age (Burrows et al., 2010)

Rankin et al carried out a review to assess reproducibility and validation of different dietary assessment methods: this review focussed mainly on South African studies and found the 24 hour recall method to have the least problems with both over- and underestimation, revealing extremely good agreement when compared with both observed intake and doubly labelled water (<11% and <4% underestimation respectively) (Rankin et al., 2010).

The 24 hour recall method used in the present study was also aided by the use of a food photo manual developed by the South African Medical Research Council (MRC) (see Chapter 4: Methods). This allowed subjects to indicate which portion size best matched the one they had consumed, enabling the interviewer to make a more accurate estimation of nutrient composition. A previous study carried out in South Africa to determine the ability of adolescents to correctly identify portions using both drawings and food models found that black adolescents were significantly better at selecting the correct portion size than their white counterparts (Steyn et al., 2006). This is a positive finding for the purposes of the present study given that subjects were exclusively of black ethnicity. Although this significant ethnic difference was found, there did not appear to be any significant gender differences in the study carried out by Steyn et al (Steyn et al., 2006).

Relevant South African studies are detailed below and where possible a comparison is made to the data of the age-matched group from the present study, i.e., age 7, 11 and 15 years.

One older South African dietary assessment study carried out on urban 5 year olds in 1984 and again in 1995 noted that diets had become more westernised over that period (MacKeown et al., 1998). In 1984 the diet consisted of a high proportion of carbohydrate and low proportion of fat, 61% and 30% respectively, however, in 1995consumption of carbohydrate was lower (52%) and fat was higher (41%) (MacKeown et al., 1998).

In 1999, a large National Food Consumption survey (NFCS) was carried out across South Africa. This was a cross-sectional study of 2,894 children aged 1 - 9 years old, which aimed to determine current nutrient intakes as well as anthropometric status (Labadarios et al., 2005). Diet was assessed by 24 hour recall and food frequency questionnaire. Other information gathered included food purchasing practices and hunger. Anthropometric status was determined based on height, weight, head and arm circumferences. Dietary results showed that energy as well as vitamins and minerals were generally below two thirds of the recommended daily allowances (these included calcium, iron, zinc, selenium, vitamins A, C, D and E, riboflavin, niacin, vitamin B6 and folic acid) (Labadarios et al., 2005). Due to the decision taken not to analyse micronutrients in the present study no comparison can be made for these results however a comparison of energy intake for the 7 - 9 year olds in the NFCS is made with the grade 1 (age 7 years) sample of children in the present study. NFCS results are shown specifically for 7 - 9 year olds living in KwaZulu-Natal (KZN) and also for those living in rural areas (see Table 7-18). Total energy consumption in the present study was similar to that of the rural sample in the NFCS and slightly less than for the KZN sample. This may be expected for the KZN sample, as it would have included all areas (rural and urban) as well as all ethnicities. A similar percentage was classed as consuming less than 50% RDA, although the proportion in the present sample was slightly lower than for both the rural and KZN samples in the NFCS.

Table 7-18 Comparison of National Food Consumption Survey (NFCS) data for 7 - 9 year olds vs present sample grade 1 (7 year olds)

	NFCS – KZN Sample	NFCS- Rural sample	Present Sample (Grade 1)
n	102	232	30
Energy Kj (Median (IQR)	7456(5466-10238)	6426(4250-9257)	6584(5368-7792)
Energy Intake <50% RDA (%)	12%	18%	10%

Data from the 24 hour recalls indicated that the most commonly consumed food items were maize, sugar, tea, whole milk and brown bread. Food security was a very prominent issue with only 25% of households being classed as food secure. In total 52% and 23% of the sample reported experiencing hunger and a risk of hunger respectively. Following the NFCS study and the high levels of micronutrient deficiency found, fortification of various foods became mandatory throughout South Africa. The commonly reported foods were similar to those found in the present study however the present study also showed evidence of fast foods making their way into the list of most commonly reported foods (as shown in Tables 7-14, 7-15 and 7-16).

Faber et al carried out a dietary assessment study in rural KwaZulu-Natal (Faber et al., 1999) where dietary intake was also assessed by a 24-hour recall and an unquantified food frequency questionnaire. The sample comprised subjects aged 10 and 11 years old; their mother or caregiver was also interviewed. Results of median energy, carbohydrate, protein and fat intake are shown in table 7-19 with a comparison to the present sample at the same age group, i.e., grade 5 (age 11 years). In the present sample total energy consumption was slightly higher than in the Faber sample, carbohydrate and protein intake were slightly lower and fat intake higher. However, although conducted over a decade ago the results are surprisingly similar to the current sample, possibly indicating that consumption has not changed drastically for rural children.

Table 7-19 Energy and macronutrient intake of Faber et al sample compared to present sample (Grade 5)

Median (95% CI)	Faber et al (Faber et al., 1999) (Age 10/11 years)	Present Study (Grade 5, Age 11 years)
n	50	42
Energy (kJ/ day)	7208 (6720, 8987)	7420 (7003, 8124)
CHO (g/day)	257 (230, 316)	243 (217, 265)
Protein (g/day)	48 (43, 57)	43 (40, 46)
Fat (g/day)	52 (49, 62)	61 (54, 71)

The study by Faber et al found that the participants diets consisted of a limited number of food items. Fruit and vegetable consumption was low, resulting in a poor intake of micronutrients. In addition to the dietary assessment measures, local food production was also assessed; from this it was found that despite local production of some vitamin A rich food crops, the quantity grown and eaten was low (Faber et al., 1999). The present study also showed low consumption of fruit and vegetables with regard to both frequency and total volume of consumption. The average number of food items appeared to increase with age in the present study (16 at grade 1 and 20 by grade 9); this may be a result of increased exposure to foods outside the home at older ages and reliance on home cooked meals at younger ages.

The South African Birth-to-Twenty study is a large birth cohort study following the health of black children in an urban township of Johannesburg from their birth in 1990 up until the age of 20 years (Richter et al., 2007). Various longitudinal dietary assessments have been carried out amongst these participants at different time points between ages 5 - 17 years (MacKeown et al., 2007, Pedro et al., 2008, Feeley et al., 2013).

Mackeown et al explored dietary intake of Birth-to-Twenty cohort subjects at ages 10 and 13 years, with a specific focus on energy, micro and macronutrient intakes (MacKeown et al., 2007). Results showed that over the period between ages 10 - 13 years there was a decrease in the percentage of participants falling below the RDA for energy, from 73% at age 10 to 59% at age 13, however, there was an increase in the number falling below the RDAs for micronutrients over this same period. Between the ages of 10 and 13 years fat, carbohydrate and protein intake changed from 25 - 29%, 63 - 60% and 12 - 11% respectively. Given that the present study was cross-sectional and not longitudinal one cannot make assumptions about change over time but can look only at differences between age groups.

Another Birth-to-Twenty study by Pedro et al used information from cohort participants at 5 different age points (5, 7, 9, 10 and 13 years) with the aim of reporting on food variety amongst the sample (Pedro et al., 2008). Over the 5 data collection points the top ten food items consumed (according to frequency of report) were rice, phutu, chicken, sugar, sweets, tea, eggs, full cream milk, carbonated beverages and oil. See table 7-16 for frequency of food consumption in the present study. The overall variety of food items reported did not vary between age 5 and 13 years, however, the ranking of the food items did change and this may suggest that there was a change in eating patterns over this time. Results of report by food group noted a decrease in frequency of reporting grains and cereals, fruits and vegetables and milk and milk products, whereas there was an increase in report of meat and meat substitutes as well as fats and oils (see table 7-17 for frequency of food groups in present sample) (Pedro et al., 2008). These changes may be considered typical of a population undergoing the nutrition transition (Popkin, 2001, Popkin et al., 2012).

One more recent study of the Birth-to-Twenty cohort presented data which assessed various eating behaviours and their link to BMI and fat mass (Feeley et al., 2013). 1,298 black adolescents were assessed longitudinally at ages 13, 15 and 17 years using an ‘unquantified’ FFQ technique and included questions regarding breakfast consumption, snacking while watching TV, eating main meal with family, use of lunchboxes, number of tuck shop purchases as well as fast food, confectionery and sweetened beverage consumption. It was intended that these measures would capture the most commonly highlighted home, community and school eating behaviours (Birch and Fisher, 1998, Guthrie et al., 2002, Story et al., 2002). Breakfast consumption was irregular especially amongst girls. Approximately one third reported never or rarely eating their main meal with family and those eating more than three TV snacks per week accounted for 50 - 70% of the sample. Over two thirds of participants consumed fast food and sweetened beverages more than 3 times per week and confectionery 7 or more times per week, use of lunchboxes was low 5 - 20% and 50 - 70% of participants purchased at least 10 school tuck shop items per week. These results are extremely worryingly especially given the level of development within this population. One possible reason given for this behaviour was aspiration to follow a western lifestyle. An association was found between dietary energy intake and proximity to food outlet (Feeley et al., 2013). It may be useful to carry out a similar study of eating behaviours and dietary habits in the present study population in order to allow comparison of results.

Strengths and weaknesses of dietary assessment conducted in the present study

The general consensus is that when conducting 24 hour recalls it is necessary to collect data on at least three non-consecutive days and that it is important to include a weekend day (Ma et al., 2009). In the present study 24 hour recall data was collected on 2 occasions, linked with collection of accelerometers and it was not always possible to include a weekend day. However, a paper regarding number of recalls needed for energy intake (Arab et al., 2010) discussed the fact that it is not possible to generalize about the number of days needed and they reported mean intake to decrease with each additional day possibly indicating that more recalls may not necessarily lead to increased validity of results. The authors also found that the importance of including a weekend day cannot be warranted without taking the mode of administration and the population into account. Another study carried out in peri-urban South African adolescents did not find multiple recalls to increase validity when compared to single recalls and suggests it is rather the interval between measurements which is important, however no ideal interval is specified (Rankin et al., 2011a).

The feasibility of dietary assessment in the present study was acceptable given the high rates of participation (78%) and high quality of data collected.

This study provides an interesting insight into the difference in eating behaviours across the age groups and may further aid in informing specific areas of diet which would be useful to target in future interventions.

Conclusions of dietary assessment in present study

There is a need for population-specific BMR estimation equations, as BMR is known to vary with several factors such as ethnicity, climate etc. (Burrows et al., 2010). Given that BMR is used in the equation for estimation of under- and overreporting, population-specific equations for BMR would in turn allow more accurate estimation of under- and overreporting prevalence.

Levels of underreporting of energy intake in this sample were apparently high, however, if the local pattern of eating is something along the lines of very low intakes punctuated by occasional high intakes for a few days (as is often the case where food insecurity is present), it might be that it would take very long periods of dietary assessment to capture this. It may also be that the periods of high intake would have to be so high to make overall typical intake physiological that the high intakes would themselves not be physiological, supporting the underreporting hypothesis.

There is of course the possibility that this ‘underreporting’ may actually be at least partly plausible given the rural, low socio-economic status of the present population and the fact that in certain circumstances energy intake may genuinely be below physiological levels but not sustainable.

Use of the 24 hour recall appeared to be a very feasible method of dietary assessment for use in this population given that it provides detailed information but is relatively quick to collect, involves little subject burden and is not as labour intensive as some alternative methods. Rates of participation in the dietary assessment were high (78%) and given the validated tools available for collection and analysis, the data collected was of a high quality.

8 Association between anthropometric measures and individual, maternal and household factors

This chapter examines the association between anthropometric measures and individual, maternal and household factors. The five anthropometric measures analysed in this chapter include BMI-for-age, using both WHO 2007 and Cole/IOTF 2000/2007 references, body fat percentage using McCarthy 2006 body fat reference, stunting (height-for-age) using WHO 2007 reference and mid-upper arm circumference (MUAC) (no reference data available). All references were analysed as dichotomous variables (overweight/overfat vs. not overweight/overfat) with the exception of MUAC which was analysed as a continuous variable given that no cut points for overweight or obesity currently exist.

Individual, maternal and household factors available in the Africa Centre datasets were included as exposures if previous studies in the literature had found them to exert an effect or if it was believed they may have the potential to affect weight or fat status.

This chapter is organised into 3 main sections:

Section 1: Analysis of association between anthropometric measures and variables from the Africa Centre Demographic Information System (ACDIS). This analysis contains the total number of participants from the cross-sectional study who were matched to their unique ACDIS information using their Bounded Structure Identifier (BSID) (n=1,320) (see Chapter 4: Methods). For each anthropometric measure the results of a descriptive analysis is included, followed by a univariable and multivariable regression and finally a multinomial regression (see Chapter 4: Methods).This is followed by a discussion of the results.

Section 2: Analysis of the association of anthropometric measures from the full cross-sectional sample (n=1,519) and lifestyle measures obtained from the lifestyle questionnaire administered to each participant (see Chapter 4: Methods). This section contains a univariable and multivariable regression analysis for each anthropometric measure and a discussion of the results.

Section 3: This section includes only those participants who took part in the sub-sample study which aimed to investigate physical activity and dietary behaviours and contains results of the exploratory analysis of the relationship between physical activity and dietary measures and anthropometric outcome and a discussion of the results.

8.1 Analysis of association between ACDIS variables and anthropometric status

8.1.1 Descriptive statistics for each anthropometric definition against each ACDIS variable

Anthropometric references used are BMI (WHO and Cole/IOTF), body fat (McCarthy) and stunting (WHO).

The descriptive statistics for BMI are classified as overweight and not overweight ; overweight includes both overweight and obese, not overweight includes individuals who are either underweight or healthy weight. The descriptive statistics for body fat are classified as overfat and not overfat; overfat includes individuals who are overfat or obese and not overfat includes individuals who are either underfat or healthy.

Where ACDIS variables are mentioned in the text, italics are used.

Weight status BMI-for-age (WHO 2007)

Table 8-1 presents the results. The only variable displaying a significant difference in overweight vs not overweight status using the WHO 2007 reference was *Sex*, with significantly more females present in the overweight category than males, 73.89% vs 26.11% respectively, $p<0.0001$. No other variables showed any significant difference between likelihood of classification as overweight or not overweight.

Table 8-1 Descriptive characteristics of overweight/obese and not overweight/obese study participants, as defined by WHO 2007 BMI-for-age reference (WHO, 2007)

	WHO		
Characteristic (N=1310)	**Not Overweight n=1130**	**Overweight n=180**	**X^2 or Mann-Whitney P value**
Sex			
Female	590 (52.21%)	133 (73.89%)	X^2 = 29.5001 p<0.0001
Male	540 (47.79%)	47 (26.11%)	
Mother's Age at Childbirth			
10-19	202 (23.76%)	26 (18.44%)	X^2 = 5.6415 p = 0.130
20-29	380 (44.71%)	68 (48.23%)	
30-39	229 (26.94%)	35 (24.82%)	
40+	39 (4.59%)	12 (8.51%)	
Missing	280	39	
Mother Alive/Dead			
Alive	573 (84.76%)	93 (86.11%)	X^2 = 0.1323 p = 0.716
Dead	103 (15.24%)	15 (13.89%)	
Missing	454	72	
Mother Co-Resident with Child			
Yes	409 (60.5%)	61(56.48%)	X^2 = 0.6272 p = 0.428
No	267 (39.5%)	47(43.52%)	
Missing	454	72	
Mother's Marital Status			
Married	196 (27.11%)	40 (33.33%)	X^2 = 2.0235 p = 0.364
Single	472 (65.28%)	71 (59.17%)	
Widowed/Separated	55 (7.61%)	9 (7.5%)	
Missing	407	60	
Number of Individuals in Household[1]			
1-5	219 (19.38%)	43 (23.89%)	X^2 = 2.3904 p = 0.303
6-15	518 (45.84%)	82 (45.56%)	
16+	393 (34.78%)	55 (30.56%)	
Missing	0	0	
Number of Individuals Under 18 in Household			
1-5	521 (46.11%)	99 (55%)	X^2 = 6.7053 p = 0.082
6-10	250 (22.12%)	32 (17.78%)	
11-15	53 (4.69%)	11 (6.11%)	
16+	306 (27.08%)	38 (21.11%)	
Missing	169	28	
Median Distance to Nearest Appropriate School (km)[2]	1.31 (0.78-1.97) (n = 1120)	1.33 (0.82-2.13) (n = 179)	Mann Whitney=-0.507 p = 0.6120
Median Distance to Level 1 Road (km)[3]	7.49 (1.2-13.49) (n = 1120)	6.78 (1.21-14.19) (n = 179)	Mann Whitney = 0.339 p = 0.7348
Water			

WHO			
Characteristic (N=1310)	**Not Overweight n=1130**	**Overweight n=180**	**X^2 or Mann-Whitney P value**
Piped	558 (70.81%)	87 (72.5%)	X^2 = 0.1442 p = 0.704
Other	230 (29.19%)	33 (27.50%)	
Missing	342	60	
Toilet			
Flush	33 (5.23%)	5 (5.26%)	X^2 = 0.4375 p = 0.804
Ventilation Pit	96 (15.21%)	12 (12.63%)	
Other	502 (79.56%)	78 (82.11%)	
Missing	499	85	
Electricity			
Yes	593 (75.45%)	95 (78.51%)	X^2 = 0.5386 p = 0.463
No	193 (24.55%)	26 (21.49%)	
Missing	344	59	
Cooking Fuel			
Electricity	451 (57.16%)	71 (58.68%)	X^2 = 1.2875 p = 0.525
Gas	46 (5.83%)	4 (3.31%)	
Wood/Coal/Other	292 (37.01%)	46 (38.02%)	
Missing	341	59	
Financial Status[4]			
Poor	159 (20.23%)	26 (21.49%)	X^2 = 3.2317p = 0.199
Just Getting By	591 (75.19%)	85 (70.25%)	
Comfortable	36 (4.58%)	10 (8.26%)	
Missing	344	59	
Adult Missed Meal[5]			
Yes	28 (3.57%)	3 (2.48%)	X^2 = 0.3779 p = 0.539
No	756 (96.43%)	118 (97.52%)	
Missing	346	59	
Asset Index[6]			
1 Poorest	157 (20.03%)	20 (16.81%)	X^2 = 5.2555 p= 0.262
2 ↓	170 (21.68%)	28 (23.53%)	
3 ↓	178 (22.7%)	19 (15.97%)	
4 ↓	175 (22.32%)	30 (25.21%)	
5 Wealthiest	104 (13.27%)	22 (18.49%)	
Missing	346	61	
Mother's Highest School Level			
Matriculation[7] and above	152 (29.63%)	25 (29.76%)	X^2 = 0.2193 p = 0.974
Some Secondary	180 (35.09%)	31 (36.9%)	
Some Primary	118 (23%)	19 (22.62%)	
Never went to school	63 (12.28%)	9 (10.71%)	
Missing	617	96	
Mother's Employment			
Employed	192 (33.33%)	32 (34.78%)	X^2 = 0.0748 p = 0.785
Not Employed	384 (66.67%)	60 (65.22%)	
Missing	554	88	

[1]Household – Social group, with individuals as members. A narrow definition would restrict the term to groups of individuals who live and eat together, but ACDIS uses a wider definition also allowing for non-resident household members. We replace "share food, prepare and eat together" by "largely share the same resources" or "care for each other/would care for each other, if need be".
A second criterion in a more or less traditional setting is that the members agree on one individual being the Household Head. If there are several heads, there are usually several households. A third criterion – imposed by the fact that much of our data collection involves interviewing proxy informants- is that members know about each other at least as far as basic information such as name, relationship to the household head, and place of residence is concerned.
Households are often families or extended families, whose members are related by blood ties or formally established relationships, but may sometimes go well beyond to also include resident domestic workers as affiliated members. They are clearly distinguished from "clans" (in the sense of relatives of common descent sharing the same forefather and surname).
While the members of a household may be spread over several places, the household itself has exactly one residence (i.e. location) at a time. At any point in time every resident individual must have membership to a household that is resident at the same place.

[2]Nearest appropriate school – This refers to the nearest school appropriate for the child's current schooling level, i.e., for those in grades 1 and 5 this is the nearest primary school and for those in grade 9 it is the nearest secondary school.

[3]Level 1 road – This refers to a main national road. Level 2 roads are district roads and level 3 roads are local roads.

[4]Financial status – This is based on the household's own perception of their financial status and therefore is a subjective measure. *Extremely poor, poor, just getting by, comfortable* and *very comfortable*, recoded here to poor (including extremely poor and poor), just getting by and comfortable (including comfortable and very comfortable).

[5]Adult missed meal – This refers to whether an adult has needed to reduce the size of meals or completely miss a meal for financial reasons at any time within the past 12 months.

[6]Asset index – This is an objective measure using a wealth index developed for use with Demographic & Health Survey data (Rutstein, 2004). This index relates to assets owned by the household as well as amenities such as water, electricity and toilet facilities available. The scale is based on quintiles from 1 - 5 with 1 being the poorest and 5 being the wealthiest.

[7]Matriculation – This is often referred to as the school exit examination although it also relates to the minimum entry requirements for enrolment at university.

Weight status BMI-for-age (Cole 2007/IOTF 2000)

Results are shown in Table 8-2. Using the Cole 2007 and IOTF 2000 references the only variable which displayed a significant difference for probability of being classed as overweight was *Sex*, with the overweight category containing significantly more females than males,80.6% vs 19.4% respectively, $p<0.0001$. No other variables showed any significant difference.

Table 8-2 Descriptive characteristics of overweight/obese and not overweight/obese study participants, as defined by IOTF 2000 and Cole 2007, BMI-for-age reference (Cole et al., 2000, Cole et al., 2007)

	IOTF		
Characteristic (N=1292)	**Not Overweight n=1163**	**Overweight n=129**	**X^2 or Mann Whitney P value**
Sex			
Female	612 (52.62%)	104 (80.62%)	X^2 = 36.8416 p<0.0001
Male	551 (47.38%)	25 (19.38%)	
Mother's Age at Childbirth			
10-19	204 (23.18%)	24 (24%)	X^2 = 5.5778 p = 0.134
20-29	394 (44.77%)	47 (47%)	
30-39	242 (27.50%)	20 (20%)	
40+	40 (4.55%)	9 (9%)	
Missing	283	29	
Mother Alive/Dead			
Alive	591 (84.91%)	68 (87.18%)	X^2 = 0.2846 p = 0.594
Dead	105 (15.09%)	10 (12.82%)	
Missing	467	51	
Mother Co-Resident with child			
Yes	416 (59.77%)	48 (61.54%)	X^2 = 0.0913 p = 0.762
No	280 (40.23%)	30 (38.46%)	
Missing	467	51	
Mother's Marital Status			
Married	204 (27.24%)	29 (33.72%)	X^2 = 1.7313 p = 0.421
Single	489 (65.29%)	52 (60.47%)	
Widowed/Separated	56 (7.48%)	5 (5.81%)	
Missing	414	43	
Number of Individuals in Household[1]			
1-5	225 (19.35%)	32 (24.81%)	X^2 = 2.2997 p = 0.317
6-15	533 (45.83%)	57 (44.19%)	
16+	405 (34.82%)	40 (31.01%)	
Missing	0	0	
Number of individuals Under 18 in Household			
1-5	543 (46.69%)	68 (52.71%)	X^2 = 4.2199 p = 0.239
6-10	252 (21.67%)	26 (20.16%)	
11-15	55 (4.73%)	9 (6.98%)	
16+	313 (26.91%)	26 (20.16%)	
Missing	0	0	
Median Distance to Nearest Appropriate School (km)[2]	1.31 (0.77-1.94)(n=1153)	1.35 (0.83-2.27)(n=128)	Mann Whitney = -1.417 p = 0.1564
Median Distance to Level 1 Road (km)[3]	7.43 (1.20-13.5)n=1153	7.14 (1.29-14.07)n=128	Mann Whitney = 0.099 p = 0.9208
Water			
Piped	573 (70.74%)	62 (73.81%)	X^2 = 0.3483 p = 0.555

IOTF			
Characteristic (N=1292)	**Not Overweight n=1163**	**Overweight n=129**	**X^2 or Mann Whitney P value**
Other	237 (29.26%)	22 (26.19%)	
Missing	353	45	
Toilet			
Flush	34 (5.25%)	4 (5.88%)	X^2 = 1.2249 p = 0.542
Ventilation Pit	99 (15.28%)	7 (10.29%)	
Other	515 (79.48%)	57 (83.82%)	
Missing	515	61	
Electricity			
Yes	612 (75.74%)	67(78.82%)	X^2 = 0.4007 p = 0.527
No	196 (24.26%)	18(21.18%)	
Missing	355	44	
Cooking Fuel			
Electricity	468 (57.71%)	49 (57.65%)	X^2 = 3.3950 p = 0.183
Gas	46 (5.67%)	1 (1.18%)	
Wood/Coal/Other	297 (36.62%)	35 (41.18%)	
Missing	352	44	
Financial Status[4]			
Poor	164 (20.27%)	20 (23.53%)	X^2 = 1.4743 p = 0.478
Just Getting By	606 (74.91%)	59 (69.41%)	
Comfortable	39 (4.82%)	6 (7.06%)	
Missing	354	44	
Adult Missed Meal[5]			
Yes	26 (3.23%)	3 (3.53%)	X^2 = 0.0225 p = 0.881
No	780 (96.77%)	82 (96.47%)	
Missing	357	44	
Asset Index[6]			
1 Poorest	160 (19.88%)	14 (16.67%)	X^2 = 4.2348 p = 0.375
2 ↓	174 (21.61%)	18 (21.43%)	
3 ↓	180 (22.36%)	13 (15.48%)	
4 ↓	181 (22.48%)	24 (28.57%)	
5 Wealthiest	110(13.66%)	15 (17.86%)	
Missing	358	45	
Mother's Highest School Level			
Matriculation[7] and above	155 (29.03%)	22 (38.60%)	X^2 = 2.3371 p = 0.505
Some Secondary	194 (36.33%)	17 (29.82%)	
Some Primary	121 (22.66%)	12 (21.05%)	
Never went to school	64 (11.99%)	6 (10.53%)	
Missing	629	72	
Mother's Employment			
Employed	201 (33.72%)	22 (33.85%)	X^2 = 0.0004 p = 0.984
Not Employed	395 (66.28%)	43 (66.15%)	
Missing	567	64	

(For definition of footnotes please see Table 8-1)

Body fatness (McCarthy 2006)

Results are shown in Table 8-3. Categorisation as overfat or not overfat was defined using McCarthy et al body fat reference (McCarthy et al., 2006). Similarly to the two BMI-for-age references, using this reference the only significant variable related to body fatness was *Sex* with a significantly higher percentage of females classed as overfat than males: 72.7% vs 27.3% respectively, p<0.0001. The remaining ACDIS variables showed no significant association of overfat compared to not overfat status.

Table 8-3 Characteristics of overfat/obese and not overfat/obese study participants, as defined by McCarthy 2006 Body fat for age reference (McCarthy et al., 2006)

BODY FAT			
Characteristic (N=1317)	**Not Overfat n=1130**	**Overfat n=187**	**X^2 or Mann-Whitney P value**
Sex			
Female	591 (52.3%)	136 (72.73%)	X^2 = 27.0709 p<0.0001
Male	539 (47.7%)	51 (27.27%)	
Mother's Age at Childbirth			
10-19	204 (23.8%)	24 (17.65%)	X^2 = 3.5127 p = 0.319
20-29	385 (44.92%)	64 (47.06%)	
30-39	226 (26.37%)	38 (27.94%)	
40+	42 (4.9%)	10 (7.35%)	
Missing	273	51	
Mother Alive/Dead			
Alive	575 (85.06%)	92 (84.40%)	X^2 = 0.0316 p = 0.859
Dead	101 (14.94%)	17 (15.6%)	
Missing	454	78	
Mother Co-Resident with child			
Yes	409 (60.5%)	62 (56.88%)	X^2 = 0.5131 p = 0.474
No	267 (39.5%)	47 (43.12%)	
Missing	454	78	
Mothers Marital Status			
Married	203 (27.92%)	34 (29.06%)	X^2 = 1.1717 p = 0.557
Single	466 (64.10%)	77 (65.81%)	
Widowed/Separated	58 (7.98%)	6 (5.13%)	
Missing	403	70	
Number of Individuals in Household[1]			
1-5	230 (20.35%)	36 (19.25%)	X^2 = 0.1937 p = 0.908
6-15	514 (45.49%)	88 (47.06%)	
16+	386 (34.16%)	63 (33.69%)	
Missing	0	0	
Number of Individuals Under 18 in Household			
1-5	527 (46.64%)	95 (50.8%)	X^2 = 1.2981 p = 0.730
6-10	245 (21.68%)	39 (20.86%)	
11-15	55 (4.87%)	9 (4.81%)	
16+	303 (26.81%)	44 (23.53%)	
Missing	0	0	
Median distance to Nearest Appropriate School (km)[2]	1.34 (0.80-1.99)	1.27 (0.72-2.05)	Mann Whitney = 0.823 p = 0.4104
Median Distance to Level 1 Road (km)[3]	7.38 (1.22-13.42)	7.52 (1.15-14.42)	Mann Whitney = 0.395 p = 0.6931
Water			
Piped	561 (70.92%)	85 (70.83%)	X^2 = 0.0004 p = 0.984
Other	230 (29.08%)	35 (29.17%)	

BODY FAT			
Characteristic (N=1317)	**Not Overfat n=1130**	**Overfat n=187**	**X^2 or Mann-Whitney P value**
Missing	339	67	
Toilet			
Flush	33 (5.22%)	5 (5.21%)	X^2 = 0.1483 p = 0.929
Ventilation Pit	95 (15.03%)	13 (13.54%)	
Other	504 (79.75%)	78 (81.25%)	
Missing	498	91	
Electricity			
Yes	595 (75.41%)	95 (78.51%)	X^2 = 0.5502 p = 0.458
No	194 (24.59%)	26 (21.49%)	
Missing	341	66	
Cooking Fuel			
Electricity	451 (57.02%)	72 (59.5%)	X^2 = 2.4350 p = 0.296
Gas	47 (5.94%)	3 (2.48%)	
Wood/Coal/Other	293 (37.04%)	46 (38.02%)	
Missing	339	66	
Financial Status[4]			
Poor	158 (20.03%)	84 (69.42%)	X^2 = 2.3585 p = 0.308
Just Getting By	593 (75.16%)	28 (23.14%)	
Comfortable	38 (4.82%)	9 (7.44%)	
Missing	341	66	
Adult Missed Meal[5]			
Yes	28(3.56%)	3 (2.48%)	X^2 = 0.3699 p = 0.543
No	759(96.44%)	118 (97.52%)	
Missing	343	66	
Asset Index[6]			
1 Poorest	158 (20.13%)	19 (15.83%)	X^2 = 2.0305 p = 0.730
2 ↓	171 (21.78%)	28 (23.33%)	
3 ↓	173 (22.04%)	24 (20%)	
4 ↓	173 (22.04%)	31 (25.83%)	
5 Wealthiest	110 (14.01%)	18 (15%)	
Missing	345	67	
Mother's Highest School Level			
Matriculation[7] and above	147 (28.49%)	31 (37.8%)	X^2 = 4.9235 p = 0.177
Some Secondary	183 (35.47%)	28 (34.15%)	
Some Primary	119 (23.06%)	18 (21.95%)	
Never went to school	67 (12.98%)	5 (6.1%)	
Missing	614	105	
Mother's Employment			
Employed	194 (33.39%)	32 (36.36%)	X^2 = 0.3020 p = 0.583
Not Employed	387 (66.61%)	56 (63.64%)	
Missing	549	99	

(For definition of footnotes please see Table 8-1)

Stunting — Height-for-age (WHO 2007)

Results are shown in Table 8-4. The WHO 2007 height-for-age reference was used to define stunting (WHO, 2007).

The variables which were shown to display significant differences in stunting status were *Sex* and the *Number of individuals in household*, with a significantly higher percentage of males classed as stunted compared to females (61.1% vs 38.9% $p<0.0001$) and participants who had more individuals in their household being significantly more likely to be stunted. Only 11.8% of participants with 1 - 5 household individuals were stunted compared to 47.9% and 40.3% of those with 6 - 15 individuals and over 16 individuals respectively ($p=0.025$).

Table 8-4 Characteristics of stunted and not stunted study participants, as defined by WHO 2007 Height-for-age reference (WHO, 2007)

	Stunting		
Characteristic N=1310	**Not Stunted n=1166**	**Stunted n=144**	**X^2 or Mann Whitney P Value**
Sex			
Female	667 (57.2%)	56 (38.89%)	X^2 = 17.39 p<0.0001
Male	499 (42.8%)	88 (61.11%)	
Mother's Age at Childbirth			
10-19	204 (22.95%)	24 (23.53%)	X^2 = 1.1065 p = 0.775
20-29	398 (44.77%)	50 (49.02%)	
30-39	241 (27.11%)	23 (22.55%)	
40+	46 (5.17%)	5 (4.9%)	
Missing	277	42	
Mother Alive/Dead			
Alive	604 (85.55%)	62 (79.49%)	X^2 = 2.0209 p = 0.155
Dead	102 (14.5%)	16 (20.51%)	
Missing	460	66	
Mother Co-Resident with child			
Yes	427 (60.48%)	43 (55.13%)	X^2 = 0.8384 p = 0.360
No	279 (39.52%)	35 (44.87%)	
Missing	460	66	
Mothers Marital Status			
Married	213 (27.99%)	23 (28.05%)	X^2 = 0.1209 p = 0.941
Single	491 (64.52%)	52 (63.41%)	
Widowed/Separated	57 (7.49%)	7 (8.54%)	
Missing	405	62	
Number of Individuals in Household[1]			
1-5	245 (21.01%)	17 (11.81%)	X^2 = 7.3382 p = 0.025
6-15	531 (45.54%)	69 (47.92%)	
16+	390 (33.45%)	58 (40.28%)	
Missing	0		
Number of Individuals Under 18 in Household			
1-5	565 (48.46%)	55 (38.19%)	X^2 = 6.1208 p = 0.106
6-10	249 (21.36%)	33 (22.92%)	
11-15	55 (4.72%)	9 (6.25%)	
16+	297 (25.47%)	47 (32.64%)	
Missing	0	0	
Median Distance to	1.33 (0.79-2.02)	1.23 (0.74-1.8)	Mann-Whitney =

Stunting			
Characteristic N=1310	**Not Stunted n=1166**	**Stunted n=144**	**X^2 or Mann Whitney P Value**
Nearest Appropriate School (km)[2]	(n=1156)	(n=143)	1.207 p = 0.2274
Median Distance to Level 1 Road (km)[3]	7.34 (1.16-13.58)(n=1156)	7.85 (1.45-14.2)(n=143)	Mann-Whitney = 0.685 p = 0.4936
Water			
Piped	576 (71.02%)	69 (71.13%)	X^2 = 0.0005 p = 0.982
Other	235 (28.98%)	28 (28.87%)	
Missing	355	47	
Toilet			
Flush	35 (5.4%)	3 (3.7%)	X^2 = 0.4938 p = 0.781
Ventilation Pit	95 (14.7%)	13 (16.05%)	
Other	515 (79.8%)	65 (80.25%)	
Missing	521	63	
Electricity			
Yes	613 (75.68%)	75 (77.32%)	X^2 = 0.1273 p = 0.721
No	197 (24.32%)	22 (22.68%)	
Missing	356	47	
Cooking Fuel			
Electricity	467 (57.44%)	55 (56.7%)	X^2 = 0.0604 p = 0.970
Gas	45 (5.54%)	5 (5.15%)	
Wood/Coal/Other	301 (37.02%)	37(38.14%)	
Missing	353	47	
Financial Status[4]			
Poor	158 (19.48%)	27 (28.13%)	X^2 = 3.9877 p = 0.136
Just Getting By	611 (75.34%)	65 (67.71%)	
Comfortable	42 (5.18%)	4 (4.17%)	
Missing	355	48	
Adult Missed Meal[5]			
Yes	26 (3.22%)	5 (5.15%)	X^2 =0.9821 p = 0.322
No	782 (96.78%)	92 (94.85%)	
Missing	533	69	
Asset Index[6]			
1 Poorest	157 (19.48%)	20 (20.62%)	X^2 = 2.3753 p = 0.667
2 ↓	174 (21.59%)	24 (24.74%)	
3 ↓	173 (21.46%)	24 (24.74%)	
4 ↓	186 (23.08%)	19 (19.59%)	
5 Wealthiest	116 (14.39%)	10 (10.31%)	
Missing	360	47	
Mother's Highest School Level			

Stunting			
Characteristic N=1310	**Not Stunted n=1166**	**Stunted n=144**	**X^2 or Mann Whitney P Value**
Matriculation[7] and above	155 (28.7%)	22 (38.6%)	X^2 = 3.2013 p = 0.362
Some Secondary	192 (3556%)	19 (33.33%)	
Some Primary	125 (23.15%)	12 (21.05%)	
Never went to school	68 (12.6%)	4 (7.02%)	
Missing	626	87	
Mother's Employment			
Employed	206 (34.05%)	18 (28.57%)	X^2 = 0.7683 p = 0.381
Not Employed	399 (65.95%)	45 (71.43%)	
Missing	561	81	

(For definition of footnotes please see Table 8-1)

8.1.2 Univariable and multivariable regression analyses of 5 anthropometric measures against ACDIS variables

Anthropometric measures included: BMI-for-age using 2 different references (WHO 2007 and Cole/IOTF 2000/2007), body fat (McCarthy 2006), stunting (WHO 2007) and mid-upper arm circumference (no reference data available).

Analysis for BMI-for-age (WHO 2007 and Cole 2007/IOTF 2000), body fat (Mccarthy 2006) and stunting (WHO 2007) measures was carried out using a logistic regression and also included school grade as a variable. Analysis for MUAC was carried out as a linear regression as no cut points were available for categorising data into overweight/overfat. Given that MUAC was a continuous variable, grade was not analysed, as the age effect cancelled out any significant difference in results. The results of this analysis are explained below.

As explained in Chapter 4: Methods, all variables were included in the univariable analysis and then variables included in the multivariable analysis were those which had reached statistical significance of $p \leq 0.05$ or where there appeared to be a trend of increasing or decreasing odds ratio between the different categories of the variable.

Weight status – BMI-for-age WHO 2007

In the univariable logistic regression investigating odds of being classed as overweight/obese (referred to as overweight) the following variables were shown to be significant: *Sex, School Grade, Mother's Age at Childbirth and Number of Individuals Under 18 in Household* (see Table 8-5) Females were at greater risk of being overweight than males. Individuals in school grade 9 had approximately double the risk of being overweight vs those in grades 5 and 1. Participants whose mothers were over 40 years old at childbirth also had significantly increased odds (approximately double) of being overweight compared to those with younger mothers. Having more individuals aged under 18 years in households decreased the risk of overweight where those with over 16 individuals under 18 in the household had an OR of 0.65 (CI 0.44-0.97, p=0.037) versus those with only 1 - 5 who had an OR of 1.00 (Reference group).

Asset Index did not reach significance in the univariable analysis however there was a trend suggesting those in the highest quintile e (i.e. wealthiest) had increased odds of being overweight, therefore it was also included in the multivariable analysis.

Multivariable analysis showed that *Sex, School grade* and *Under 18s in Household* all remained significant with *Mother's age at childbirth* failing to reach significance at this stage and the trend apparent for *Asset Index* also not reaching significance.

Table 8-5 Univariable and multivariable regression analysis of ACDIS variables to analyse risk of overweight/obese, defined by WHO 2007 BMI-for-age reference

WHO Regression Analysis					
Characteristic N=1310	**Events (Total)**	**Unadjusted (OR) (CI)**	**p**	**Adjusted (OR) (CI)**	**p**
Sex					
Female	133/723	1.00	-	1.00	-
Male	47/587	0.39 (0.27-0.55)	<0.0001	0.40 (0.28-0.57)	<0.0001
School Grade					
9	81/409	1.00	-	1.00	-
5	46/450	0.46 (0.31-0.68)	<0.0001	0.50 (0.33-0.75)	0.001
1	53/451	0.54 (0.37-0.79)	0.001	0.65 (0.44-0.96)	0.032
Mother's Age at Childbirth					
10-19	26/228	1.00	-	1.00	-
20-29	68/448	1.39 (0.86-2.25)	0.181	1.46 (0.89-2.4)	0.135
30-39	35/264	1.19 (0.69-2.04)	0.534	1.05 (0.60-1.83)	0.871
40+	12/51	2.39 (1.11-5.14)	0.026	2.0 (0.90-4.45)	0.090
Missing	39/319	1.08 (0.64-1.84)	0.770	1.04 (0.58-1.84)	0.906
Mother Alive/Dead					
Alive	93/666	1.00	-	—	—
Dead	15/118	0.89 (0.5-1.61)	0.716	—	—
Missing	72/526	0.98 (0.70-1.36)	0.891	—	—
Mother Co-Resident with child					
Yes	61/470	1.00	-	—	—
No	47/314	1.18 (0.78-1.78)	0.429	—	—
Missing	72/526	1.06 (0.74-1.53)	0.742	—	—
Mother's Marital Status					
Married	40/236	1.00	-	—	—
Single	71/543	0.74 (0.48-1.12)	0.156	—	—
Widowed/Separated	9/64	0.8 (0.37-1.75)	0.580	—	—
Missing	60/467	0.72 (0.47-1.12)	0.143	—	—

WHO Regression Analysis					
Characteristic N=1310	**Events (Total)**	**Unadjusted (OR) (CI)**	**p**	**Adjusted (OR) (CI)**	**p**
Number of Individuals in Household[1]					
1-5	43/262	1.00	-	—	—
6-15	82/600	0.81 (0.54-1.2)	0.293	—	—
16+	55/448	0.71 (0.46-1.1)	0.124	—	—
Missing	-	-	-	—	—
Number of Individuals Under 18 in Household					
1-5	99/620	1.00	-	1.00	-
6-10	32/282	0.67 (0.44-1.03)	0.069	0.64 (0.41-0.99)	0.044
11-15	11/64	1.09 (0.55-2.16)	0.800	1.04 (0.51-2.1)	0.920
16+	38/344	0.65 (0.44-0.97)	0.037	0.59 (0.36-0.95)	0.031
Missing	-	-	-	-	-
Median Distance to Nearest Appropriate School(km)[2]		1.04 (0.87-1.23)	0.670	—	—
Median Distance to Level 1 Road (km)[3]		0.99 (0.97-1.02)	0.613	—	—
Water					
Piped	87/645	1.00	-	—	—
Other	33/263	0.92 (0.6-1.41)	0.704	—	—
Missing	60/402	1.12 (0.79-1.61)	0.515	—	—
Toilet					
Other	78/580	1.00	-	—	—
Flush	5/38	0.98 (0.37-2.57)	0.959	—	—
Ventilation Pit	12/108	0.8 (0.42-1.53)	0.509	—	—
Missing	85/584	1.1 (0.79-1.53)	0.587	—	—
Electricity					
Yes	95/688	1.00	-	—	—
No	26/219	0.84 (0.53-1.34)	0.463	—	—
Missing	59/403	1.07(0.75-1.52)	0.703	—	—
Cooking Fuel					

WHO Regression Analysis					
Characteristic N=1310	**Events (Total)**	**Unadjusted (OR) (CI)**	**p**	**Adjusted (OR) (CI)**	**p**
Electricity	71/522	1.00	-	—	—
Gas	4/50	0.55 (0.19-1.58)	0.269	—	—
Wood/Coal/Other	46/338	1.0 (0.67-1.49)	0.997	—	—
Missing	59/400	1.1 (0.76-1.6)	0.620	—	—
Financial Status[4]					
Poor	26/185	1.14 (0.71-1.82)	0.595	—	—
Just Getting By	85/676	1.00	-	—	—
Comfortable	10/46	1.93 (0.92-4.03)	0.080	—	—
Missing	59/403	1.19 (0.83-1.71)	0.335	—	—
Adult Missed Meal[5]					
Yes	3/31	0.69 (0.21-2.3)	0.541	—	—
No	118/874	1.00	-	—	—
Missing	59/405	1.09 (0.78-1.53)	0.607	—	—
Asset Index[6]					
1 Poorest	20/177	1.00	-	1.00	-
2 ↓	28/198	1.29 (0.7-2.39)	0.412	1.19 (0.64-2.24)	0.584
3 ↓	19/197	0.84 (0.43-1.63)	0.601	0.78 (0.40-1.54)	0.478
4 ↓	30/205	1.35 (0.73-2.47)	0.336	1.26 (0.68-2.35)	0.465
5 Wealthiest	22/126	1.66 (0.86-3.19)	0.129	1.59 (0.81-3.13)	0.178
Missing	61/407	1.38 (0.81-2.37)	0.237	1.69 (0.94-3.04)	0.080
Mother's Education					
Matriculation[7] and above	25/177	1.00	-	—	—
Some Secondary	31/211	1.05 (0.59-1.85)	0.874	—	—
Some Primary	19/137	0.98 (0.51-1.86)	0.948	—	—
Never went to school	9/72	0.87 (0.38-1.97)	0.735	—	—
Missing	96/713	0.95 (0.59-1.52)	0.819	—	—
Mother's Employment					
Employed	32/224	1.00	-	—	—

WHO Regression Analysis					
Characteristic N=1310	**Events (Total)**	**Unadjusted (OR) (CI)**	**p**	**Adjusted (OR) (CI)**	**p**
Not Employed	60/444	0.94 (0.59-1.49)	0.785	—	—
Missing	88/642	0.95 (0.62-1.47)	0.829	—	—

(For definition of footnotes please see Table 8-1)

Weight status –BMI-for-age Cole 2007/Cole/IOTF 2000

Univariable logistic regression investigating odds of being classed as overweight/obese (referred to as overweight), using the Cole 2007/IOTF 2000 reference found *Sex* and *School Grade* to be significant (see Table 8-6).

Females were at greater risk of overweight than males, and individuals in school grade 9 had increased risk vs those in grades 5 and 1.

Number of Individuals in Household showed a non-significant trend with participants who lived in households with a greater number of individuals having a decreased risk of being classed as overweight.

Multivariable analysis showed that *Sex* and *School Grade* both remained significant ($p<0.05$), however, the trend apparent for *Number of Individuals in Household* still did not reach significance.

Table 8-6 Univariable and multivariable regression analysis of ACDIS variables to analyse risk of overweight/obese, defined by Cole 2007/IOTF 2000 BMI-for-age reference (Cole et al., 2007, Cole et al., 2000)

Cole/IOTF Regression Analysis					
Characteristic N=1292	**Events (Total)**	**Unadjusted (OR) (CI)**	**p**	**Adjusted (OR)(CI)**	**p**
Sex					
Female	104/716	1.00	-	1.00	-
Male	25/576	0.27 (0.17-0.42)	<0.0001	0.29 (0.19-0.46)	<0.0001
School Grade					
9	67/391	1.00	-	1.00	-
5	34/450	0.40 (0.26-0.61)	<0.0001	0.42 (0.27-0.66)	<0.0001
1	28/451	0.32 (0.20-0.51)	<0.0001	0.37 (0.23-0.59)	<0.0001
Mother's Age at Childbirth					
10-19	24/228	1.00	-	—	—
20-29	47/441	1.01 (0.6-1.71)	0.958	—	—
30-39	20/262	0.7 (0.38-1.31)	0.266	—	—
40+	9/49	1.9 (0.83-4.42)	0.129	—	—
Missing	29/312	0.87 (0.49-1.54)	0.635	—	—
Mother Alive/Dead					
Alive	68/659	1.00	-	—	—
Dead	10/115	0.83 (0.41-1.66)	0.594	—	—
Missing	51/518	0.95 (0.65-1.39)	0.789	—	—
Mother Co-Resident with child					
Yes	48/464	1.00	-	—	—
No	30/310	0.93 (0.57-1.5)	0.763	—	—
Missing	51/518	0.95 (0.62-1.43)	0.795	—	—
Mother's Marital Status					
Married	29/233	1.00	-	—	—
Single	52/541	0.75 (0.46-1.21)	0.239	—	—
Widowed/Separated	5/61	0.63 (0.23-1.7)	0.359	—	—
Missing	43/457	0.73 (0.44-1.2)	0.219	—	—

Cole/IOTF Regression Analysis					
Characteristic N=1292	**Events (Total)**	**Unadjusted (OR) (CI)**	**p**	**Adjusted (OR)(CI)**	**p**
Number of Individuals in Household[1]					
1-5	32/257	1.00	-	1.00	-
6-15	57/590	0.75 (0.47-1.19)	0.225	0.75 (0.47-1.21)	0.243
16+	40/445	0.69 (0.42-1.14)	0.147	0.77 (0.46-1.27)	0.303
Missing	-	-	-	-	-
Number of Individuals Under 18 in Household					
1-5	68/611	1.00	-	—	—
6-10	26/278	0.82 (0.51-1.33)	0.425	—	—
11-15	9/64	1.31 (0.62-2.76)	0.484	—	—
16+	26/339	0.66 (0.41-1.06)	0.089	—	—
Missing	-	-	-		
Median Distance to Nearest Appropriate School(km)[2] n=1281		1.14 (0.94-1.38)	0.178	—	—
Median Distance to Level 1 Road(km)[3] n=1281		1.0 (0.97-1.02)	0.762	—	—
Water					
Piped	62/635	1.00	-	—	—
Other	22/259	0.86 (0.52-1.43)	0.555	—	—
Missing	45/398	1.18 (0.78-1.77)	0.429	—	—
Toilet					
Other	57/572	1.00	-	—	—
Flush	4/38	1.06 (0.36-3.1)	0.911	—	—
Ventilation Pit	7/106	0.64 (0.28-1.44)	0.281	—	—
Missing	61/576	1.07 (0.73-1.57)	0.727	—	—
Electricity					
Yes	67/679	1.00	-	—	—
No	18/214	0.84 (0.49-1.45)	0.527	—	—
Missing	44/399	1.13 (0.76-1.69)	0.545	—	—

Cole/IOTF Regression Analysis					
Characteristic N=1292	**Events (Total)**	**Unadjusted (OR) (CI)**	**p**	**Adjusted (OR)(CI)**	**p**
Cooking Fuel					
Electricity	49/517	1.00	-	—	—
Gas	1/47	0.21 (0.03-1.54)	0.124	—	—
Wood/Coal/Other	35/332	1.13 (0.71-1.78)	0.612	—	—
Missing		1.19 (0.78-1.84)	0.419	—	—
Financial Status[4]					
Poor	20/184	1.25 (0.73-2.14)	0.410	—	—
Just Getting By	59/665	1.00	-	—	—
Comfortable	6/45	1.58 (0.64-3.89)	0.319	—	—
Missing	44/398	1.28 (0.85-1.93)	0.245	—	—
Adult Missed Meal[5]					
Yes	3/29	1.1 (0.33-3.7)	0.881	—	—
No	82/862	1.00	-	—	—
Missing	44/401	1.17 (0.8-1.73)	0.421	—	—
Asset Index[6]					
1 Poorest	14/174	1.00	-	—	—
2 ↓	18/192	1.18 (0.57-2.45)	0.653	—	—
3 ↓	13/193	0.83 (0.38-1.8)	0.632	—	—
4 ↓	24/205	1.52 (0.76-3.03)	0.239	—	—
5 Wealthiest	15/125	1.56 (0.72-3.36)	0.257	—	—
Missing	45/403	1.44 (0.77-2.69)	0.258	—	—
Mother's Education					
Matriculation[7] and above	22/177	1.00	-	—	—
Some Secondary	17/211	0.62 (0.32-1.2)	0.157	—	—
Some Primary	12/133	0.7 (0.33-1.47)	0.344	—	—
Never went to school	6/70	0.66 (0.26-1.71)	0.391	—	—
Missing	72/701	0.81 (0.48-1.34)	0.407	—	—
Mother's Employment					

Cole/IOTF Regression Analysis					
Characteristic N=1292	**Events (Total)**	**Unadjusted (OR) (CI)**	**p**	**Adjusted (OR)(CI)**	**p**
Employed	22/223	1.00	-	—	—
Not Employed	43/438	0.99 (0.58-1.71)	0.984	—	—
Missing	64/631	1.03 (0.62-1.72)	0.906	—	—

(For definition of footnotes please see Table 8-1)

Weight Status, as defined by BMI Z-score

BMI Z-score was run as a continuous variable in a linear regression, however, there were no results of further significance other than those outlined above, with only *Sex* showing a statistically significant difference, so the results of this analysis are not presented here.

Body fatness (McCarthy 2006)

Univariable logistic regression investigating odds of being classed as overfat/obese (referred to as overfat) found *Sex, School Grade and Mother's Education* to be significant (Table 8-7). Females were at significantly greater risk of overfat than males. Individuals in school grade 9 had increased risk compared to those in grade 5, although individuals in school grade 1 appeared to have a slightly increased risk compared to individuals in grade 9, however, this was not statistically significant.

Mother's Education was a significant predictor of overfat status where participants of mothers who had no schooling had a significantly decreased risk of being classed overfat compared to those whose mothers had completed matriculation.

Mother's Age at Childbirth showed a trend where participants with older mothers were at increased risk of overfatness, however, this trend was not significant at the univariable level.

Multivariable analysis showed that *Sex, School Grade* and *Mothers Education* all remained significant; the trend apparent for *Mothers Age at Childbirth* in the univariable analysis also reached significance at the multivariable level; individuals whose mothers were over 40 years at childbirth were almost three times as likely to be classed as overfat compared to those whose mothers were 10 - 19 years old at childbirth.

Table 8-7 Univariable and multivariable regression analysis of ACDIS variables to analyse risk of overfat/obesity, defined by McCarthy 2006 body fat for age reference (McCarthy et al., 2006)

Body Fat Regression Analysis					
Characteristic N=1317	**Events (Total)**	**Unadjusted (OR) (CI)**	**p**	**Adjusted (OR) (CI)**	**p**
Sex					
Female	136/727	1.00	-	1.00	-
Male	51/590	0.41 (0.29-0.58)	<0.0001	0.40 (0.28-0.57)	<0.0001
School Grade					
9	72/418	1.00	-	1.00	-
5	32/451	0.37 (0.24-0.57)	<0.0001	0.38 (0.25-0.60)	<0.0001
1	83/448	1.09 (0.77-1.55)	0.618	1.2 (0.83-1.72)	0.329
Mother's Age at Childbirth					
10-19	24/228	1.00	-	1.00	-
20-29	64/449	1.41 (0.86-2.33)	0.174	1.62 (0.97-2.73)	0.067
30-39	38/264	1.43 (0.83-2.46)	0.199	1.51 (0.85-2.68)	0.155
40+	10/52	2.02 (0.9-4.54)	0.088	2.73 (1.13-6.59)	0.026
Missing	51/324	1.59 (0.95-2.67)	0.080	1.65 (0.92-2.95)	0.095
Mother Alive/Dead					
Alive	92/667	1.00	-	—	—
Dead	17/118	1.05 (0.6-1.84)	0.859	—	—
Missing	78/532	1.07 (0.78-1.49)	0.668	—	—
Mother Co-Resident with child					
Yes	62/471	1.00	-	—	—
No	47/314	1.16 (0.77-1.75)	0.474	—	—
Missing	78/532	1.13 (0.79-1.62)	0.495	—	—
Mothers Marital Status					
Married	34/237	1.00	-	—	—
Single	77/543	0.99 (0.64-1.53)	0.951	—	—
Widowed/Separated	6/64	0.62 (0.25-1.54)	0.302	—	—
Missing	70/473	1.04 (0.67-1.62)	0.872	—	—

Body Fat Regression Analysis					
Characteristic N=1317	**Events (Total)**	**Unadjusted (OR) (CI)**	**p**	**Adjusted (OR) (CI)**	**p**
Number of Individuals in Household[1]					
1-5	36/266	1.00	-	—	—
6-15	88/602	1.09 (0.72-1.66)	0.674	—	—
16+	63/449	1.04 (0.67-1.62)	0.852	—	—
Missing	-	-	-	—	—
Number of Individuals Under 18 in Household					
1-5	95/622	1.00	-	—	—
6-10	39/284	0.88 (0.59-1.32)	0.545	—	—
11-15	9/64	0.91 (0.43-1.9)	0.797	—	—
16+	44/347	0.81 (0.55-1.18)	0.270	—	—
Missing	-	-		—	—
Median Distance to Nearest Appropriate School(km)[2] n=1306		0.97 (0.82-1.15)	0.748		
Median Distance to Level 1 Road(km)[3] n=1306		1.0 (0.98-1.03)	0.611	—	—
Water					
Piped	85/646	1.00	-	—	—
Other	35/265	1.0 (0.66-1.53)	0.984	—	—
Missing	67/406	1.3 (0.92-1.85)	0.134	—	—
Toilet					
Other	78/582	1.00	-	—	—
Flush	5/38	0.98 (0.37-2.58)	0.966	—	—
Ventilation Pit	13/108	0.88 (0.47-1.65)	0.700	—	—
Missing	91/589	1.18 (0.85-1.64)	0.319	—	—
Electricity					
Yes	95/690	1.00	-	—	—
No	26/220	0.84 (0.53-1.33)	0.459	—	—
Missing	66/407	1.21 (0.86-1.71)	0.269	—	—

Body Fat Regression Analysis					
Characteristic N=1317	**Events (Total)**	**Unadjusted (OR) (CI)**	**p**	**Adjusted (OR) (CI)**	**p**
Cooking Fuel					
Electricity	72/523	1.00	-	—	—
Gas	3/50	0.4 (0.12-1.32)	0.132	—	—
Wood/Coal/Other	46/339	0.98 (0.66-1.46)	0.934	—	—
Missing	66/405	1.22 (0.85-1.75)	0.283	—	—
Financial Status[4]					
Poor	28/186	1.25 (0.79-1.99)	0.342	—	—
Just Getting By	84/677	1.00	-	—	—
Comfortable	9/47	1.67 (0.78-3.58)	0.186	—	—
Missing	66/407	1.37 (0.96-1.94)	0.079	—	—
Adult Missed Meal[5]					
Yes	3/31	0.69 (0.21-2.3)	0.545	—	—
No	118/877	1.00	-	—	—
Missing	66/409	1.24 (0.89-1.72)	0.201	—	—
Asset Index[6]					
1 Poorest	19/177	1.00	-	—	—
2 ↓	28/199	1.36 (0.73-2.53)	0.330	—	—
3 ↓	24/197	1.15 (0.61-2.19)	0.661	—	—
4 ↓	31/204	1.49 (0.81-2.74)	0.200	—	—
5 Wealthiest	18/128	1.36 (0.68-2.71)	0.381	—	—
Missing	67/412	1.61 (0.94-2.78)	0.084	—	—
Mother's Education					
Matriculation[7] and above	31/178	1.00	-	1.00	-
Some Secondary	28/211	0.73 (0.42-1.26)	0.257	0.74 (0.42-1.31)	0.297
Some Primary	18/137	0.72 (0.38-1.35)	0.301	0.64 (0.33-1.24)	0.189
No Schooling	5/72	0.35 (0.13-0.95)	0.039	0.30 (0.11-0.86)	0.025
Missing	105/719	0.81 (0.52-1.26)	0.350	0.78 (0.47-1.3)	0.338
Mother's Employment					

Body Fat Regression Analysis					
Characteristic N=1317	**Events (Total)**	**Unadjusted (OR) (CI)**	**p**	**Adjusted (OR) (CI)**	**p**
Employed	32/226	1.00	-	—	—
Not Employed	56/443	0.88 (0.55-1.40)	0.583	—	—
Missing	99/648	1.09 (0.71-1.68)	0.685	—	—

(For definition of footnotes please see Table 8-1)

Stunting status, defined by Height-for-age WHO 2007

Univariable analysis of stunted individuals compared to not stunted individuals showed *Sex, School Grade, Number of Individuals in Household, Number of Individuals Under 18 in Household* and *Financial Status*, all to be significant predictors of the odds of being stunted (Table 8-8). Males were twice as likely to be stunted as females. There was little difference between stunting risk of children in school grades 9 and 5, however, children in grade 1 had significantly increased risk. *Number of Individuals in Household* and *Number of Individuals Under 18 in Household* both displayed an increased risk of stunting the higher the number in household; for *Number of Individuals in Household* risk increased progressively as total increased. *Number of Individuals Under 18 in Household* displayed a similar association but with a slightly weaker association. In terms of *Financial Status*, being "poor" had an increased risk of stunting vs those who claimed to be "just getting by". The above variables remained significant at the multivariable level with the exception of *School Grade* which failed to reach any significance and *Financial status* which was on the borderline of significance (p=0.06).

Trends noticed, and which were therefore included in multivariable analysis were *Asset Index* and *Mother's Education*. Increase in *Asset Index* quintile (ie increased wealth) appeared to show a decreased risk of stunting. *Mother's Education* interestingly showed a clear trend in contrast to what would be expected with decreased level of schooling exerting a decreased risk, this however was not significant but was interesting to note.

Other trends noted but not included in multivariable analysis were *Mother Alive/Dead status* and *Mother Co-resident with child*, both showed a slight trend where mother being dead and mother not co-resident both resulted in increased odds of being stunted. Although not statistically significant this may suggest a possible protective effect of having one's mother around. *Mother's Age at Childbirth* also showed a weak trend of slightly decreased risk of stunting if the mother was older.

Table 8-8 Univariable and multivariable regression analysis of ACDIS variables to analyse risk of stunting, defined by WHO 2007 Height-for-age reference (WHO, 2007)

Stunting Regression Analysis					
Characteristic N=1310	**Events (Total) n=144**	**Unadjusted (OR) (CI)**	**p**	**Adjusted (OR) (CI)**	**p**
Sex					
Female	56/723	1.00	-	1.00	-
Male	88/587	2.1 (1.47-2.99)	<0.0001	2.08 (1.45-2.99)	<0.0001
School Grade					
9	38/409	1.00	-	1.00	-
5	41/450	0.98 (0.62-1.56)	0.927	0.84 (0.52-1.36)	0.489
1	65/451	1.64 (1.07-2.5)	0.022	1.31 (0.84-2.05)	0.235
Mother's Age at Childbirth					
10-19	24/228	1.00	-	—	—
20-29	50/448	1.07 (0.64-1.79)	0.803	—	—
30-39	23/264	0.81 (0.44-1.48)	0.495	—	—
40+	55/51	0.92 (0.33-2.55)	0.879	—	—
Missing	42/319	1.29 (0.76-2.2)	0.351	—	—
Mother Alive/Dead					
Alive	62/666	1.00	-	—	—
Dead	16/118	1.53 (0.85-2.75)	0.158	—	—
Missing	66/526	1.4 (0.97-2.02)	0.074	—	—
Mother Co-Resident with child					
Yes	43/470	1.00	-	—	—
No	35/314	1.25 (0.78-2.0)	0.361	—	—
Missing	66/526	1.42 (0.95-2.14)	0.088	—	—
Mother's Marital Status					
Married	23/236	1.00	-	—	—
Single	52/543	0.98 (0.59-1.64)	0.941	—	—
Widowed/Separated	7/64	1.14 (0.46-2.78)	0.778	—	—
Missing	62/467	1.42 (0.85-2.35)	0.177	—	—

Stunting Regression Analysis					
Characteristic N=1310	**Events (Total) n=144**	**Unadjusted (OR) (CI)**	**p**	**Adjusted (OR) (CI)**	**p**
Number of Individuals in Household[1]					
1-5	17/262	1.00	-	1.00	-
6-15	69/600	1.87 (1.08-3.25)	0.026	2.08 (1.13-3.83)	0.019
16+	58/448	2.14 (1.22-3.77)	0.008	1.2 (0.53-2.75)	0.662
Missing	-	-	-	-	-
Number of Individuals Under 18 in Household					
1-5	55/620	1.00	-	1.00	-
6-10	33/282	1.36 (0.86-2.15)	0.185	1.26 (0.76-2.07)	0.369
11-15	9/64	1.68 (0.79-3.58)	0.179	2.51 (0.87- 7.29)	0.090
16+	47/344	1.63 (1.07-2.46)	0.021	2.50 (1.1-5.66)	0.029
Missing	-	-	-	-	-
Median Distance to Nearest Appropriate School(km)[2] n=1299		0.85 (0.70-1.05)	0.131	—	—
Median Distance to Level 1 Road(km)[3] n=1299		1.01 (0.98-1.03)	0.672	—	—
Water					
Piped	69/645	1.00	-	—	—
Other	28/263	0.99 (0.62-1.58)	0.982	—	—
Missing	47/402	1.11 (0.75-1.64)	0.618	—	—
Toilet					
Other	65/580	1.00	-	—	—
Flush	3/38	0.68 (0.2-2.27)	0.530	—	—
Ventilation Pit	13/108	1.08 (0.57-2.04)	0.803	—	—
Missing	63/584	0.96 (0.66-1.38)	0.819	—	—
Electricity					
Yes	75/688	1.00	-	—	—
No	22/219	0.91 (0.55-1.51)	0.721	—	—
Missing	47/403	1.08	0.700	—	—

Stunting Regression Analysis					
Characteristic N=1310	**Events (Total) n=144**	**Unadjusted (OR) (CI)**	**p**	**Adjusted (OR) (CI)**	**p**
		(0.73-1.59)			
Cooking Fuel					
Electricity	55/522	1.00	-	—	—
Gas	5/50	0.94 (0.36-2.48)	0.906	—	—
Wood/Coal/Other	37/338	1.04 (0.67-1.62)	0.849	—	—
Missing	47/400	1.13 (0.75-1.71)	0.561	—	—
Financial Status[4]					
Poor	27/185	1.61 (0.99-2.6)	0.054	1.66 (0.98-2.81)	0.060
Just Getting By	65/676	1.00	-	1.00	-
Comfortable	4/46	0.9 (0.31-2.58)	0.837	0.93 (0.31-2.77)	0.899
Missing	48/403	1.27 (0.86-1.89)	0.234	6.97 (0.75-64.4)	0.087
Adult Missed Meal[5]					
Yes	5/26	1.63 (0.61-4.36)	0.326	—	—
No	92/874	1.00	-	—	—
Missing	47/405	1.12 (0.77-1.62)	0.564	—	—
Asset Index[6]					
1 Poorest	20/177	1.00	-	1.00	-
2 ↓	24/198	1.08 (0.58-2.04)	0.805	1.21 (0.62-2.33)	0.578
3 ↓	24/197	1.09 (0.58-2.05)	0.791	1.15 (0.59-2.24)	0.683
4 ↓	19/205	0.8 (0.41-1.56)	0.514	0.88 (0.43-1.81)	0.736
5 Wealthiest	10/126	0.68 (0.31-1.5)	0.336	0.75 (0.32-1.79)	0.524
Missing	47/407	1.02 (0.59-1.79)	0.931	0.12 (0.01-1.19)	0.070
Mother's Education					
Matriculation[7] and above	22/177	1.00	-	1.00	-
Some Secondary	19/211	0.7 (0.36-1.33)	0.276	0.64 (0.33-1.25)	0.193
Some Primary	12/137	0.68 (0.32-1.42)	0.302	0.65 (0.30-1.42)	0.285
Never went to school	4/72	0.41 (0.14-1.25)	0.117	0.41 (0.13-1.27)	0.123
Missing	87/713	0.98 (0.59-1.61)	0.934	1.01 (0.57-1.78)	0.986

Stunting Regression Analysis					
Characteristic N=1310	**Events (Total) n=144**	**Unadjusted (OR) (CI)**	**p**	**Adjusted (OR) (CI)**	**p**
Mother's Employment					
Employed	18/224	1.00	-	—	—
Not Employed	45/444	1.29 (0.73-2.29)	0.382	—	—
Missing	81/642	1.65 (0.97-2.82)	0.066	—	—

(For definition of footnotes please see Table 8-1)

Mid-upper arm circumference (MUAC) (reference data unavailable therefore analysed as a continuous variable)

Of the 18 variables analysed 12 were significant at the univariable level, these were *Sex, Mothers Age at Childbirth, Mother Alive/Dead, Mothers Marital Status, Number of Individuals in Household, Number of Individuals Under 18 in Household, Distance to School, Distance to Road, Toilet, Financial Status, Asset Index and Mothers Education* (Table 8-9).

In the multivariable analysis only 6 of the 12 remained significant, these were *Sex, Mother Marital Status, Number of Individuals Under 18 in Household, Distance to school, Asset Index, Mothers Education*. Being male, having a single mother and having over 16 under 18s in the household all decreased the risk of a high MUAC whereas being in the wealthiest asset index category, having a longer distance to school and having a mother who never went to school appear to increase risk. The remaining 6 (*Mother Alive/Dead, Mother's Age at Childbirth, Number of Individuals in Household, Distance to Road, Toilet and Financial Status*) did not reach significance.

Table 8-9 Univariable and multivariable regression analysis of ACDIS variables to analyse risk of high MUAC

MUAC Linear Regression				
Characteristic N=1320	**Unadjusted Coefficient (95% CI)**	**P value**	**Adjusted Coefficient (95% CI)**	**P value**
Sex				
Female	Reference	-	Reference	-
Male	-1.46 (-1.88 , -1.04)	<0.0001	-1.36 (-1.76, -0.96)	<0.0001
Mother's Age at Childbirth				
10-19	Reference	-	Reference	-
20-29	0.86 (0.24, 1.48)	0.006	0.46 (-0.14, 1.06)	0.130
30-39	0.46 (-0.22, 1.15)	0.186	-0.63 (-1.34, 0.08)	0.083
40+	2.01 (0.84, 3.19)	0.001	0.60 (-0.58, 1.78)	0.319
Missing	0.39(-0.27, 1.04)	0.252	-0.04 (-1.06, 0.99)	0.946
Mother Alive/Dead				
Alive	Reference	-	Reference	-
Dead	0.69 (-0.07, 1.45)	0.077	0.26 (-0.72, 1.24)	0.603
Missing	-0.74 (-1.18, -0.30)	0.001	-1.02 (-1.64, -0.40)	0.001
Mother Co-Resident with child				
Yes	Reference	-	—	—
No	-0.11 (-0.67, 0.44)	0.695	—	—
Missing	-0.89 (-1.37, -0.4)	<0.0001	—	—
Mother's Marital Status				
Married	Reference	-	Reference	-
Single	-1.65 (-2.24, -1.06)	<0.0001	-1.35 (-1.96, -0.74)	<0.0001
Widowed/Separated	0.23 (-0.84, 1.29)	0.675	0.05 (-0.98, 1.07)	0.930
Missing	-0.74 (-1.35, -0.14)	0.015	0.43 (-0.52, 1.38)	0.375
Number of Individuals in Household[1]				
1-5	Reference	-	Reference	-
6-15	-0.03 (0.59, 0.53)	0.911	-0.12 (-0.68, 0.45)	0.686
16+	-0.84 (-1.43, -0.25)	0.005	-0.41 (-1.30,0.47)	0.362
Missing	-	-	-	-
Number of Individuals Under 18 in Household				
1-5	Reference	-	Reference	-
6-10	-0.27 (-0.81, 0.28)	0.335	-0.35 (-0.92, 0.22)	0.232
11-15	-0.52 (-1.52, 0.48)	0.312	-0.35 (-1.57,0.87)	0.572
16+	-1.07 (-1.58,-0.56)	<0.0001	-1.08 (-1.97, -0.19)	0.018
Missing	-	-	-	-
Median distance to Nearest Appropriate School(km)[2]	1.08 (0.85, 1.3)	<0.0001	0.91 (0.67,1.15)	<0.0001
	0.06 (0.03, 0.09)	<0.0001	0.02 (-0.02, 0.05)	0.369

MUAC Linear Regression				
Characteristic N=1320	**Unadjusted Coefficient (95% CI)**	**P value**	**Adjusted Coefficient (95% CI)**	**P value**
Median Distance to Level 1 Road(km)[3]				
Water				
Piped	Reference	-	—	—
Other	-0.28 (-0.84, 0.28)	0.325	—	—
Missing	-0.22 (-0.7,0.27)	0.379	—	—
Toilet				
Other	Reference	-	Reference	-
Flush	1.57 (0.29, 2.85)	0.016	1.18 (-0.09, 2.44)	0.068
Ventilation Pit	-0.18 (-0.98, 0.63)	0.668	-0.07 (-0.83,0.68)	0.850
Missing	-0..09 (-0.54, 0.35)	0.681	-0.13 (-0.80,0.55)	0.715
Electricity				
Yes	Reference	-	—	—
No	-0.02 (-0.62, 0.57)	0.935	—	—
Missing	-0.12 (-0.60, 0.36)	0.612	—	—
Cooking Fuel				
Electricity	Reference	-	—	—
Gas	-0.34 (-1.47, 0.80)	0.563	—	—
Wood/Coal/Other	0.21 (-0.33, 0.74)	0.448	—	—
Missing	-0.01 (-0.52, 0.49)	0.954	—	—
Financial Status[4]				
Poor	-0.66 (-1.29, -0.02)	0.042	-0.47 (-1.09, 0.15)	0.138
Just Getting By	Reference	-	Reference	-
Comfortable	0.76 (-0.39, 1.92)	0.196	0.04 (-1.06, 1.14)	0.942
Missing	-0.21 (-0.69,0.27)	0.395	-0.74 (-2.79,1.31)	0.481
Adult Missed Meal[5]				
Yes	-0.86 (-2.26, 0.54)	0.227	—	—
No	Reference	-	—	—
Missing	-0.16 (-0.62,0.30)	0.500	—	—
Asset Index[6]				
1 Poorest	Reference	-	Reference	-
2 ↓	0.70 (-0.09, 1.49)	0.082	0.56 (-0.21, 1.33)	0.154
3 ↓	-0.02 (-0.81, 0.77)	0.965	0.2 (-0.6, 1.0)	0.627
4 ↓	0.52 (-0.26, 1.31)	0.190	0.77 (-0.07, 1.61)	0.071
5 Wealthiest	1.05 (0.16, 1.94)	0.020	1.3 (0.31, 2.29)	0.010
Missing	0.34 (-0.35, 1.02)	0.337	1.96 (-0.13,4.04)	0.066
Mother's Education				
Matriculation[7] and above	Reference	-	Reference	-
Some Secondary	0.23 (-0.55, 1.01)	0.560	0.18 (-0.55, 0.92)	0.626
Some Primary	1.13 (0.26,2.0)	0.011	0.80 (-0.06, 1.65)	0.068
Never went to school	1.50 (0.43, 2.56)	0.006	1.11 (0.03,2.19)	0.043
Missing	0.63 (-0.01, 1.27)	0.054	0.11 (-0.66,0.89)	0.778

MUAC Linear Regression				
Characteristic N=1320	**Unadjusted Coefficient (95% CI)**	**P value**	**Adjusted Coefficient (95% CI)**	**P value**
Mother's Employment				
Employed	Reference	-	—	—
Not Employed	0.06 (-0.57, 0.69)	0.852	—	—
Missing	0.25 (-0.35, 0.84)	0.413	—	—

(For definition of footnotes please see Table 8-1)

8.1.3 Multinomial analysis for BMI (WHO and Cole/IOTF) and body fat (McCarthy 2006) references

In additional to the uni and multivariable analysis carried out, a multinomial analysis was also carried out on BMI and body fat. This involved categorising the references into underweight/healthy/overweight and underfat/healthy/overfat for BMI and body fat respectively rather than using the numerical result used in the uni and multivariable analysis.

The purpose of this analysis was to determine differences between risk factors for overweight and underweight, because of this only BMI-for-age references (WHO and IOTF) and the body fat reference (McCarthy 2006) were analysed. MUAC and height-for-age were not analysed here given that MUAC was a continuous variable with no specific categorical cut points and height-for-age cannot define weight or body fat status.

Weight status – BMI-for-age (WHO 2007)

Being male carried an increased risk of being underweight but decreased risk for overweight compared to being healthy and also compared to being female (Table 8-10).

Table 8-10 Multinomial analysis of ACDIS variables for risk of underweight and overweight as defined by WHO 2007 BMI-for-age reference

WHO Multinomial Analysis					
Characteristic N=1310	**Underweight RRR (95% CI)**	**p**	**Healthy Reference**	**Overweight RRR (95% CI)**	**p**
Sex					
Female	-	-		-	-
Male	2.83 (1.44-5.59)	0.003		0.4 (0.28-0.57)	<0.0001
Mother's Age at Childbirth					
10-19	-	-		-	-
20-29	0.73 (0.32-1.68)	0.466		1.37 (0.85-2.23)	0.201
30-39	0.79 (0.31-1.97)	0.608		1.17 (0.68-2.02)	0.561
40+	2.46e-06 (0 - .)	0.977		2.27 (1.06-4.89)	0.036
Missing	0.64 (0.25-1.60)	0.338		1.06 (0.63-1.80)	0.822
Mother Alive/Dead					
Alive	-	-		-	-
Dead	1.22 (0.45-3.29)	0.694		0.91 (0.50-1.63)	0.739
Missing	0.76 (0.39-1.50)	0.428		0.97 (0.69-1.35)	0.847
Mother CoResident					
Yes	-	-		-	-
No	0.99 (0.46-2.15)	0.981		1.18 (0.78-1.78)	0.431
Missing	0.73 (0.36-1.51)	0.399		1.05 (0.73-1.52)	0.788
Mother's Marital Status					
Married	-	-		-	-
Single	1.07 (0.44-2.61)	0.881		0.74 (0.48-1.13)	0.161
Widowed/Separated	1.02 (0.21-5.05)	0.982		0.80 (0.37-1.76)	0.582
Missing	1.03 (0.41-2.58)	0.944		0.72 (0.47-1.12)	0.145
Individuals in Household[1]					
1-5	-	-		-	-
6-15	1.17 (0.51-2.67)	0.709		0.81 (0.54-1.21)	0.309
16+	0.83 (0.33-2.06)	0.690		0.71 (0.46-1.09)	0.119
Missing	-	-		-	-

WHO Multinomial Analysis					
Characteristic N=1310	**Underweight RRR (95% CI)**	**p**	**Healthy Reference**	**Overweight RRR (95% CI)**	**p**
Under 18s in Household					
1-5	-	-		-	-
6-10	1.37 (0.67-2.81)	0.384		0.68 (0.45-1.05)	0.081
11-15	1.5 (0.43-5.23)	0.522		1.11 (0.56-2.21)	0.760
16+	0.5 (0.2-1.26)	0.142		0.64 (0.43-0.96)	0.030
Missing	-	-		-	-
Median Distance to Nearest Appropriate School (km)[2](n=1299)	1.18 (0.87-1.62)	0.283		1.05 (0.88-1.24)	0.614
Median Distance to Level 1 Road (km)[3](n=1299)	0.99 (0.94-1.04)	0.656		0.99 (0.97-1.02)	0.591
Water					
Piped	-	-		-	-
Other	0.52 (0.19-1.38)	0.187		0.90 (0.59-1.39)	0.638
Missing	0.99 (0.50-1.96)	0.983		1.12 (0.79-1.61)	0.518
Toilet					
Other	-	-		-	-
Flush	6.48e-06 (1.9e-284-2.2e+273)	0.971		0.93 (0.35-2.47)	0.891
Ventilation Pit	0.49 (0.11-2.11)	0.337		0.79 (0.41-1.5)	0.469
Missing	0.91 (0.48-1.71)	0.762		1.09 (0.78-1.52)	0.604
Electricity					
Yes	-	-		-	-
No	0.83 (0.33-2.08)	0.696		0.84 (0.53-1.33)	0.448
Missing	1.1 (0.56-2.18)	0.782		1.07 (0.76-1.53)	0.689
Cooking Fuel					
Electricity	-	-		-	-
Gas	1.16 (0.26-5.19)	0.846		0.56 (0.19-1.59)	0.275
Wood/Coal/Other	0.81 (0.36-1.85)	0.619		0.99 (0.67-1.48)	0.975
Missing	1.09 (0.53-2.25)	0.809		1.10 (0.76-1.6)	0.608
Financial Status[4]					
Just Getting By	-	-		-	-

WHO Multinomial Analysis					
Characteristic N=1310	**Underweight RRR (95% CI)**	**p**	**Healthy Reference**	**Overweight RRR (95% CI)**	**p**
Poor	2.77 (1.2-6.35)	0.016		1.18 (0.74-1.9)	0.484
Comfortable	5.15 (1.6-16.54)	0.006		2.12 (1.01-4.47)	0.048
Missing	1.75 (0.82-3.71)	0.146		1.21 (0.85-1.74)	0.290
Adult Missed Meal[5]					
No	-	-		-	-
Yes	1 (0.13-7.63)	1.00		0.69 (0.20-2.30)	0.542
Missing	1.14 (0.59-2.20)	0.699		1.1 (0.78-1.54)	0.589
Asset Index[6]					
1 Poorest	-	-		-	-
2 ↓	2.14 (0.65-7.09)	0.214		1.33 (0.71-2.46)	0.363
3 ↓	1.11 (0.29-4.19)	0.883		0.84 (0.43-1.63)	0.607
4 ↓	1.12 (0.30-4.27)	0.862		1.35 (0.74-2.48)	0.332
5 Wealthiest	1.93 (0.51-7.37)	0.335		1.7 (0.88-3.28)	0.113
Missing	1.61 (0.52-4.98)	0.406		1.41 (0.82-2.41)	0.217
Mother's Highest School Level					
Matriculation[7] and above	-	-		-	-
Some Secondary	0.98 (0.32-2.99)	0.978		1.05 (0.59-1.85)	0.876
Some Primary	0.85 (0.24-3.10)	0.810		0.97 (0.51-1.85)	0.935
Never went to school	0.39 (0.05-3.33)	0.391		0.85 (0.37-1.92)	0.692
Missing	0.98 (0.40-2.45)	0.974		0.95 (0.59-1.52)	0.817
Mother's Employment					
Employed	-	-		-	-
Not Employed	0.74 (0.30-1.85)	0.521		0.93 (0.58-1.47)	0.750
Missing	0.95 (0.42-2.17)	0.905		0.95 (0.61-1.47)	0.823

(For definition of footnotes please see Table 8-1)

Weight status BMI-for-age (Cole 2007/IOTF 2000)

As was the case for the WHO BMI reference, being male carried an increased risk of being underweight but decreased risk for overweight compared to being healthy and also compared to being female (Table 8-11).

The risk of being underweight decreased as *Mother's Age at Childbirth* increased but this did not reach significance.

Table 8-11 Multinomial analysis of ACDIS variables for risk of underweight and overweight/obese, as defined by Cole 2007/IOTF 2000 BMI-for-age reference

IOTF Multinomial Analysis					
Characteristic N=1292	**Underweight RRR (95% CI)**	**p**	**Healthy Reference**	**Overweight RRR (95% CI)**	**p**
Sex					
Female	-	-		-	-
Male	1.20 (0.86-1.67)	0.290		0.27 (0.17-0.43)	<0.0001
Mother's Age at Childbirth					
10-19	-	-		-	-
20-29	0.74 (0.46-1.19)	0.209		0.97 (0.57-1.64)	0.911
30-39	0.88 (0.52-1.47)	0.616		0.69 (0.37-1.29)	0.243
40+	0.42 (0.12-1.44)	0.168		1.73 (0.74-4.03)	0.202
Missing	0.90 (0.55-1.48)	0.687		0.86 (0.48-1.52)	0.600
Mother Alive/Dead					
Alive	-	-		-	-
Dead	0.48 (0.23-1.03)	0.060		0.77 (0.38-1.54)	0.454
Missing	1.0 (0.71-1.41)	0.997		0.95 (0.65-1.40)	0.791
Mother CoResident					
Yes	-	-		-	-
No	0.66 (0.41-1.05)	0.079		0.88 (0.54-1.43)	0.605
Missing	0.94 (0.65-1.36)	0.732		0.94 (0.62-1.43)	0.762
Mother's Marital Status					
Married	-	-		-	-
Single	1.18 (0.72-1.92)	0.516		0.76 (0.47-1.24)	0.279
Widowed/Separated	1.95 (0.91-4.19)	0.086		0.70 (0.26-1.92)	0.489
Missing	1.12 (0.68-1.85)	0.660		0.74 (0.45-1.23)	0.245
Number of Individuals in Household[1]					
1-5	-	-		-	-
6-15	1.1 (0.69-1.75)	0.693		0.76 (0.48-1.21)	0.249
16+	1.27 (0.79-2.1)	0.326		0.72 (0.44-1.18)	0.191
Missing					

IOTF Multinomial Analysis					
Characteristic N=1292	**Underweight RRR (95% CI)**	**p**	**Healthy Reference**	**Overweight RRR (95% CI)**	**p**
Number of Individuals Under 18 in Household					
1-5	-	-		-	-
6-10	1.14 (0.75-1.76)	0.539		0.84 (0.52-1.36)	0.475
11-15	1.3 (0.61-2.77)	0.496		1.36 (0.64-2.90)	0.429
16+	1.12 (0.75-1.67)	0.592		0.67 (0.42-1.08)	0.104
Missing					
Median Distance to Nearest Appropriate School(km)[2] (n=1281)	1.09 (0.91-1.31)	0.339		1.15 (0.95-1.40)	0.143
Median Distance to Level 1 Road (km)[3](n=1281)	0.99 (0.97-1.01)	0.426		0.99 (0.97-1.02)	0.689
Water					
Piped	-	-		-	-
Other	0.81 (0.52-1.28)	0.366		0.83 (0.5-1.39)	0.488
Missing	0.94 (0.64-1.37)	0.743		1.17 (0.78-1.76)	0.459
Toilet					
Other	-	-		-	-
Flush	1.60 (0.67-3.80)	0.292		1.15 (0.39-3.41)	0.799
Ventilation Pit	0.85 (0.44-1.63)	0.622		0.63 (0.28-1.42)	0.261
Missing	0.98 (0.69-1.4)	0.928		1.07 (0.73-1.57)	0.738
Electricity					
Yes	-	-		-	-
No	0.92 (0.58-1.48)	0.739		0.83 (0.48-1.44)	0.505
Missing	0.97 (0.66-1.41)	0.859		1.13 (0.75-1.69)	0.564
Cooking Fuel					
Electricity	-	-		-	-
Gas	0.57 (0.20-1.64)	0.298		0.19 (0.03-1.45)	0.110
Wood/Coal/Other	1.01 (0.67-1.53)	0.950		1.13 (0.71-1.79)	0.610
Missing	0.95 (0.63-1.41)	0.781		1.18 (0.77-1.83)	0.444

IOTF Multinomial Analysis					
Characteristic N=1292	**Underweight RRR (95% CI)**	**p**	**Healthy Reference**	**Overweight RRR (95% CI)**	**p**
Financial Status[4]					
Just Getting By	-	-		-	-
Poor	2.43 (1.56-3.78)	0.000		1.45 (0.84-2.50)	0.180
Comfortable	2.41 (1.1-5.3)	0.028		1.83 (0.73-4.57)	0.198
Missing	1.26 (0.85-1.88)	0.250		1.31 (0.87-1.99)	0.197
Adult Missed Meal[5]					
No	-	-		-	-
Yes	1.89 (0.74-4.81)	0.183		1.23 (0.36-4.23)	0.741
Missing	1.0 (0.69-1.44)	0.997		1.17 (0.79-1.73)	0.424
Asset Index[6]					
1 Poorest	-	-		-	-
2 ↓	0.75 (0.41-1.37)	0.350		1.13 (0.54-2.36)	0.741
3 ↓	0.79 (0.44-1.44)	0.446		0.80 (0.36-1.76)	0.573
4 ↓	0.61 (0.33-1.14)	0.122		1.42 (0.70-2.85)	0.329
5 Wealthiest	0.96 (0.5-1.85)	0.912		1.55 (0.71-3.36)	0.269
Missing	0.78 (0.47-1.3)	0.344		1.38 (0.73-2.61)	0.315
Mother's Highest School Level					
Matriculation[7] and above	-	-		-	-
Some Secondary	0.77 (0.41-1.46)	0.426		0.60 (0.31-1.17)	0.133
Some Primary	1.27 (0.66-2.44)	0.473		0.73 (0.34-1.54)	0.401
Never went to school	0.74 (0.3-1.84)	0.519		0.64 (0.24-1.65)	0.353
Missing	1.01 (0.61-1.67)	0.971		0.81 (0.48-1.35)	0.415
Mother's Employment					
Employed	-	-		-	-
Not Employed	1.11 (0.68-1.81)	0.680		1.01 (0.58-1.74)	0.974
Missing	1.01 (0.63-1.62)	0.958		1.03 (0.62-1.73)	0.901

(For definition of footnotes please see Table 8-1)

Analysis of effect of ACDIS variables on body fat

Being male carried a significantly increased risk of being underfat ($p<0.0001$) and significantly decreased risk of being overfat (p 0.002) compared to being female (Table 8-12).

Table 8-12 Multinomial analysis of ACDIS variables for risk of underweight and overweight as defined by McCarthy 2006 Body fat for age reference

Body Fat Multinomial Analysis					
Characteristic N=1317	**Underfat RRR (95% CI)**	**p**	**Healthy Reference**	**Overfat RRR (95% CI)**	**p**
Sex					
Female	-	-		-	-
Male	3.25 (2.48-4.26)	<0.0001		0.58 (0.41-0.83)	0.002
Mother's Age at Childbirth					
10-19	-	-		-	-
20-29	1.21 (0.84-1.75)	0.313		1.50 (0.90-2.50)	0.121
30-39	0.95 (0.62-1.45)	0.810		1.41 (0.81-2.46)	0.229
40+	0.67 (0.30-1.49)	0.325		1.83 (0.80-4.19)	0.153
Missing	0.97 (0.65-1.44)	0.864		1.57 (0.92-2.67)	0.095
Mother Alive/Dead					
Alive	-	-		-	-
Dead	1.31 (0.84-2.04)	0.230		1.15 (0.64-2.06)	0.633
Missing	0.83 (0.63-1.09)	0.190		1.02 (0.73-1.42)	0.913
Mother CoResident					
Yes	-	-		-	-
No	0.94 (0.67-1.31)	0.718		1.14 (0.75-1.74)	0.545
Missing	0.78 (0.58-1.05)	0.097		1.05 (0.73-1.52)	0.782
Mothers Marital Status					
Married	-	-		-	-
Single	0.81 (0.57-1.16)	0.251		0.93 (0.59-1.45)	0.738
Widowed/Separated	1.18 (0.64-2.17)	0.599		0.65 (0.26-1.67)	0.375
Missing	0.85 (0.59-1.22)	0.379		0.99 (0.62-1.56)	0.953
Individuals in Household[1]					
1-5	-	-		-	-
6-15	0.79 (0.56-1.1)	0.168		1.02 (0.66-1.57)	0.933
16+	0.91 (0.64-1.29)	0.598		1.01 (0.64-1.59)	0.959
Missing	-	-		-	-

Body Fat Multinomial Analysis					
Characteristic N=1317	**Underfat RRR (95% CI)**	**p**	**Healthy Reference**	**Overfat RRR (95% CI)**	**p**
Under 18s in Household					
1-5	-	-		-	-
6-10	1.09 (0.78-1.51)	0.611		0.91 (0.60-1.37)	0.641
11-15	1.08 (0.59-1.98)	0.794		0.93 (0.43-1.99)	0.851
16+	0.99 (0.73-1.35)	0.956		0.80 (0.54-1.19)	0.278
Missing	-	-		-	-
Median Distance to Nearest Appropriate School (km)[2](n=1306)	1.2 (1.05-1.38)	0.008		1.03 (0.86-1.23)	0.735
Median Distance to Level 1 Road (km)[3](n=1306)	1.0 (0.98-1.02)	0.894		1.0 (0.98-1.03)	0.599
Water					
Piped	-	-		-	-
Other	0.75 (0.53-1.05)	0.096		0.92 (0.60-1.42)	0.716
Missing	0.82 (0.61-1.11)	0.200		1.23 (0.86-1.76)	0.256
Toilet					
Other	-	-		-	-
Flush	2.19 (1.07-4.46)	0.031		1.30 (0.47-3.61)	0.614
Ventilation Pit	1.21 (0.75-1.95)	0.427		0.94 (0.49-1.78)	0.840
Missing	1.14 (0.87-1.5)	0.339		1.23 (0.88-1.72)	0.233
Electricity					
Yes	-	-		-	-
No	1.25 (0.88-1.76)	0.210		0.90 (0.56-1.45)	0.665
Missing	0.93 (0.70-1.26)	0.652		1.19 (0.84-1.69)	0.334
Cooking Fuel					
Electricity	-	-		-	-
Gas	1.21 (0.63-2.31)	0.565		0.42 (0.13-1.42)	0.164
Wood/Coal/Other	1.33 (0.97-1.84)	0.073		1.08 (0.71-1.62)	0.727
Missing	0.99 (0.72-1.36)	0.948		1.22 (0.84-1.77)	0.304
Financial Status[4]					
Just Getting By	-	-		-	-
Poor	1.51	0.029		1.43	0.144

Body Fat Multinomial Analysis					
Characteristic N=1317	**Underfat RRR (95% CI)**	**p**	**Healthy Reference**	**Overfat RRR (95% CI)**	**p**
	(1.04-2.18)			(0.89-2.31)	
Comfortable	1.32 (0.66-2.63)	0.438		1.82 (0.82-4.04)	0.140
Missing	0.98 (0.73-1.31)	0.877		1.36 (0.95-1.94)	0.095
Adult Missed Meal[5]					
No					
Yes	1.50 (0.69-3.25)	0.307		0.79 (0.23-2.75)	0.714
Missing	0.89 (0.67-1.18)	0.404		1.20 (0.85-1.67)	0.299
Asset Index[6]					
1 Poorest	-	-		-	-
2 ↓	1.07 (0.68-1.68)	0.776		1.39 (0.73-2.65)	0.311
3 ↓	0.70 (0.44-1.12)	0.134		1.03 (0.54-1.99)	0.919
4 ↓	0.85 (0.54-1.35)	0.492		1.41 (0.75-2.65)	0.280
5 Wealthiest	0.60 (0.34-1.03)	0.065		1.17 (0.58-2.38)	0.658
Missing	0.73 (0.49-1.1)	0.131		1.47 (0.84-2.56)	0.179
Mother's Highest School Level					
Matriculation[7] and above	-	-		-	-
Some Secondary	1.08 (0.67-1.75)	0.747		0.74 (0.42-1.31)	0.307
Some Primary	1.08 (0.63-1.84)	0.785		0.73 (0.38-1.4)	0.347
Never went to school	1.18 (0.63-2.22)	0.606		0.37 (0.14-1.02)	0.054
Missing	1.11 (0.74-1.65)	0.620		0.83 (0.53-1.31)	0.436
Mother's Employment					
Employed	-	-		-	-
Not Employed	1.20 (0.82-1.75)	0.360		0.92 (0.57-1.49)	0.747
Missing	1.11 (0.77-1.6)	0.563		1.12 (0.72-1.75)	0.596

(For definition of footnotes please see Table 8-1)

8.1.4 Discussion of analysis of association between ACDIS variables and anthropometric status

Main Findings

Descriptive analysis found *Sex* to be the only variable which had a significant association with classification as overweight/overfat or not overweight/overfat, with being female having a significantly higher risk of being classified as overweight/overfat compared to being male. This association was seen for both BMI references (WHO and Cole/IOTF), as well as for the body fat reference (McCarthy). Factors affecting risk of stunting were *Sex* and *Number of individuals in household*, where being male and having a higher number of individuals in household both increased risk.

Univariable and multivariable analysis of factors found *Sex, School Grade* and *Number of 18s in household* to have a significant effect on BMI using the WHO reference; with being female, being in grade 9 and having a smaller number of individuals under the age of 18 in the household all resulting in increased odds of being classified as overweight. However using the Cole/IOTF BMI reference only *Sex* and *School Grade* were found to have a significant association with weight status.

Analysis of the body fat reference found *Sex, School Grade, Mothers Education* and *Mothers Age at Childbirth* to be significant at the multivariable level; with being female, enrolled in school grade 9, having a mother who had completed matriculation and who was over 40 years old at time of giving birth all resulting in an increased risk of being classified as overfat.

Stunting analysis found *Sex, Number of individuals in household* and *Number of under 18s in household* to have a significant effect on stunting status where being male and having a higher number of individuals and under 18s in household increased risk of stunting. Investigating associations of stunting was not a main aim of the present study, however, the results were included for interest.

Given the lack of reference data for MUAC measurements the regression carried out was linear; factors found to have a significant effect on MUAC measurement were *Sex, Mothers marital status, Number of under 18s in household, Distance to school, Asset index* *and Mothers education*. Being male, having a single mother and having over 16 individuals under the age of 18 in the household all significantly decreased risk of a high MUAC, whereas being in the wealthiest asset index category and having a mother who never went to school appear to increase risk.

A multinomial analysis was also carried out on BMI (WHO and Cole/IOTF) and body fat (McCarthy) data, results showed *Sex* was the only variable to have a significant effect, where being male significantly increased the risk of being classified as underweight/underfat and significantly decreased risk of being classified as overweight/overfat.

Implications

Sex is the most consistent variable throughout the analysis with female sex resulting in a significantly increased risk of being classified as overweight or overfat. Being in a higher school grade also presented an increased risk for all measures of weight and fat status. These results may suggest that prevention strategies to tackle overweight and obesity in this sample should be aimed at females before they become overweight and that other household level factors do not appear to have a consistent significant association.

Stunting appears to be a condition more commonly associated with the males in the present sample and also appears to be affected by household level influences such as number of total individuals in household and number of under 18s in household; these factors should be taken into consideration when taking preventative action on stunting.

Given that there are no references available, one must be careful in making assumptions relating to MUAC measurements, as high measurements may be a result of either increased muscle mass or increased fat mass. Chapter 6 presents possible MUAC cut points to be used for classification as overweight, however, this research is novel and further MUAC research is required to assess the use of MUAC in classification of overweight and obesity and to aid in the development of internationally recognised cut points. A further analysis using MUAC data to determine potential cut points has been undertaken (see Chapter 6: MUAC) but they are tentative and the suggested cut-points are not included in the analysis shown here.

Comparisons with other studies

To the best of the author's knowledge only three previous studies have been carried out in South Africa with the aim of investigating socio-economic predictors of anthropometric status (Kimani-Murage et al., 2011, Labadarios et al., 2005, Sheppard et al., 2009). One of the studies was a national study and formed part of the South Africa National Food Consumption Survey in 1999, where 2,894 children aged 1 - 9 years were sampled from across South Africa. The survey included a variety of measures including anthropometry (height, weight, head circumference and MUAC) and questionnaires on socio-demographics, dietary intake, hunger and food procurement (Labadarios et al., 2005). Prevalence of overweight and obesity (defined as a BMI $\geq 25 kg/m^2$) in 1 - 9 year olds was 17.1% and socio-demographic determinants found to be associated with overweight included type of housing, type of toilet, fuel used in cooking, presence of refrigerator/stove, television in the house and education levels of both caregiver and mother. These determinants were also found for stunting, and, as might be expected, were found to be directionally opposite in their risk. For example using paraffin as a fuel was protective against being overweight but predictive of being stunted (Labadarios et al., 2005).

More recently a study was carried out using data from a sample of 888 individuals who are part of the Birth-to-Twenty cohort (a study discussed previously in Chapter 7) (Sheppard et al., 2009). Socio-economic status at birth was compared with anthropometric outcome at age 7 - 8 years to examine the influence of socio-economics on weight status. Household ownership of a car, a telephone and having an inside flush toilet were all positively associated with BMI, weight-for-age z-score (WAZ) and weight-for-height z-score (WHZ). Another factor with a significant positive association with both BMI and weight-for-height z-score (WHZ) was ownership of a television, while being born in a private hospital was positively associated with weight-for-age z-score (WAZ)(Sheppard et al., 2009). It is unclear exactly why these difference were not shown in our sample however it may be due to the different population and setting of the present study compared to the studies referred to above and also as a result of the homogeneity in the present sample.

The most recent South African study conducted in a rural area of the Limpopo province known as the Agincourt sub-district, aimed to investigate the predictors of adolescent weight status and included 1,848 adolescents aged 10 - 20 years (Kimani-Murage et al., 2011). Individuals aged 10 - 17 years and 18 - 20 years had their overweight status defined by IOTF and WHO cut points respectively. Similar to the present study, analyses found girls were at a significantly increased risk of overweight and obesity compared to boys. Other factors which also increased risk were being in the highest socio-economic status households, having a mother aged ≥50 years and being post pubertal. Neither socio-economic status nor mother's age were significant factors in the present study possibly due to the homogeneity of the sample. Pubertal status was not assessed in the present sample and therefore a comparison of these results cannot be made. Kimani-Murage et al found that the odds of central obesity (measured by waist-to-height ratio) increased by 10% for each unit increase in age. Decreased risk of overweight and obesity was found if the head of the household had not completed secondary education. This study looked only at the predictors of adolescent weight status and not those of child weight status (Kimani-Murage et al., 2011).

A recent multilevel analyses conducted on n=2,100 children who were part of the early childhood longitudinal study in the US assessed the ecological influences on obesity in early childhood (Boonpleng et al., 2013). The study found that child and family factors accounted for 71% of the variance in overweight and obesity, while school and community level factors accounted for 27% and 2% respectively. The authors suggest these results imply interventions should firstly focus on factors relating to the child and family, then at the school level and finally at the community level. It is not clear whether the results would be the same in a low - middle income country, although the results of the present study also show individual level factors to have the most consistent effect. Other studies have also noted a link between maternal, child and family factors and risk of overweight and obesity (Sousa, 2009, Birch and Davison, 2001).

A description of studies examining predictors of stunting has been discussed previously in Chapter 5: Prevalence. Evidence suggests that stunting is often a function of early programming (Chapter 1: Introduction, section 1.3.5) and in low income countries is more common amongst individuals in the lower socio-economic class whilst overweight and obesity are more commonly associated with individuals in the higher socio-economic class. In the Birth-to-Twenty cohort in individuals aged <30 months, having a mother who is employed, a father who has completed secondary education and parents who employ a domestic worker were all associated with decreased risk of stunting, while being male and having a low birth weight appeared to increase the risk (Willey et al., 2009). However, one interesting point to note is that the South African study by Sheppard et al mentioned above found that none of the 12 socio-economic variables analysed were associated with height-for-age z-score (HAZ)(Sheppard et al., 2009)

To the best of the author's knowledge no other studies have looked at the socio-economic predictors of MUAC and therefore no comparison can be made to other studies.

Strengths and weaknesses of analysis to determine association between ACDIS variable and anthropometric status

Few studies have carried out analyses of higher level influences on anthropometric outcome and there is a distinct lack of data from sub-saharan Africa, therefore the present study contributes to the current evidence base.

Household data were not available for every subject (see Chapter 4: Methods). Some did not provide a valid household identifier, i.e., BSID at the time of measurement and therefore this made it difficult to match them to their data (although every effort was taken to match each individual via other methods such as mother's and father's name). Where an individual had not been matched, analysis of higher level influences could not be carried out and therefore the present analysis does not include all 1,519 subjects initially enrolled in the study. Of those included in the analysis, results appear to show that higher level influences were not very influential. Pubertal status was not assessed in the present study, but given that it has been highlighted as a possible risk factor in previous work (Kimani-Murage et al., 2011), it may be beneficial to include this measure in any future research to further understand the change in weight and fatness that occur in girls between 7 and 15 years.

Conclusion

Further research is required in this area to better inform the development of future interventions, however, current results imply the majority of variation is at the individual level although some higher level factors may also have an influence.

8.2 Associations between anthropometric measures and study participant's responses to the lifestyle questionnaire

This section provides results of the analyses between different anthropometric measures and participants' responses to the interviewer-administered lifestyle questionnaire (see Chapter 4: Methods and Appendix 10). The aim here was to assess the association of overweight/obesity or overfat/obesity (referred to here as overweight and overfat respectively) as a result of different lifestyle habits. As well as BMI and body fat, MUAC was also analysed as a continuous variable.

All variables were analysed in the univariable analysis, however, only those which reached significance $p \leq 0.05$ or which showed evidence of a trend were included in the multivariable analysis.

Weight status, as defined by BMI-for-age WHO 2007

Of the lifestyle questions asked to each participant (n = 1,519) *School Travel* and *Sport Participation* were the only two found to be associated with classification as overweight by WHO 2007 standards (Table 8-13). Walking to school was associated with a decreased risk of being classed as overweight compared to travelling to school in a motor vehicle. Reporting no participation in sport significantly increased risk of classification as overweight compared to those who reported participation. Both of these variables also remained significant in a multivariable analysis.

Table 8-13 Univariable and multivariable regression analysis of lifestyle variables to analyse risk of overweight, as defined by WHO 2007, BMI-for-age reference

			WHO		
Characteristic	**Events (Total)**	**Unadjusted OR**	**P Value**	**Adjusted OR**	**P Value**
Collect Water	1507				
Yes	174/1258	1.00	-	—	—
No	34/249	0.99 (0.66, 1.46)	0.941	—	—
Frequency of Water Collection					
At least once a day	114/840	1.00	-	—	—
2-6 times a week	53/326	1.24 (0.87, 1.76)	0.241	—	—
Once a week	6/64	0.66 (0.28, 1.56)	0.343	—	—
Missing	35/277	0.92 (0.61, 1.38)	0.691	—	—
Time taken to collect water (one way) mins	1507	1.00 (1.00, 1.00)	0.761	—	—
School Travel					
Motor Vehicle	45/243	1.00	-	1.00	-
Walk	162/1257	0.65 (0.45, 0.94)	0.021	0.69 (0.48, 0.99)	0.047
Bicycle	0/2	-	-	-	-
Missing	1/5	1.1 (0.12, 10.08)	0.933	1.1 (0.12, 10.13)	0.934
Time taken to travel to school	1507	1.00 (1.00, 1.00)	0.761	—	—
Electricity at Home					
Yes	164/1147	1.00	-	—	—
No	44/359	0.84 (0.59,1.20)	0.328	—	—
Missing	0/1	-	-	—	—
TV at Home					
Yes	162/1155	1.00	-	—	—
No	46/351	0.92 (0.65, 1.31)	0.662	—	—
Missing	0/1	-	-	—	—
Where TV watched					
Own home	164/1129	1.00	-	—	—

Someone else home	23/209	0.73 (0.46, 1.16)	0.179	—	—
Missing	21/169	0.83 (0.51, 1.36)	0.467	—	—
TV hours watched daily	1507	0.998 (0.99, 1.00)	0.673	—	—
Sport Participation					
Yes	91/797	1.00	-	1.00	-
No	117/710	1.53 (1.14, 2.06)	0.005	1.49 (1.10, 2.00)	0.009

Weight status, as defined by BMI-for-age Cole 2007/IOTF 2000

As was the case for the BMI-for-age WHO 2007 reference, the only variables found to have a significant association with classification as overweight (using Cole2007/IOTF200 reference) were *School Travel* and *Sport Participation* (Table 8-14). Walking to school had decreased odds of overweight compared to travelling by motor vehicle and not participating in sport had increased odds of overweight compared to those who did participate in sport. Both these variables remained significant at the multivariable level.

It also appeared that having no electricity at home, no TV at home and watching TV at someone else's home, as opposed to in one's own home, all led to a slightly decreased risk of being classed as overweight, however, none of these observations reached significance. Frequency of water collection also showed a slight trend where decreased collection frequency led to a decreased risk of overweight. Again this did not reach significance and seems a puzzling trend.

Table 8-14 Univariable and multivariable regression analysis of lifestyle variables to analyse risk of overweight, as defined by Cole 2007/IOTF 2000 BMI-for-age reference

		IOTF			
Characteristic	**Events (Total)**	**Unadjusted OR**	**P Value**	**Adjusted OR**	**P Value**
Collect Water					
Yes	123/1244	1.00	-	—	—
No	26/242	1.10 (0.70, 1.72)	0.685	—	—
Frequency of Water Collection					
At least once a day	85/830	1.00	-	—	—
2-6 times a week	32/322	0.97 (0.63,1.48)	0.879	—	—
Once a week	5/64	0.74 (0.29, 1.90)	0.535	—	—
Missing	27/270	0.97 (0.62, 1.54)	0.909	—	—
Time taken to collect water (one way)	1486	1.00 (0.999, 1.00)	0.820		
School Travel					
Motor Vehicle	36/243	1.00		1.00	
Walk	112/1236	0.57 (0.38, 0.86)	0.007	0.61 (0.40, 0.91)	0.016
Bicycle	0/2	-	-	-	-
Missing	1/5	1.44 (0.16, 13.23)	0.749	1.44 (0.16, 13.33)	0.748
Time taken to travel to school		1.00 (0.998, 1.00)	0.345	—	—
Electricity at Home					
Yes		1.00	-	—	—
No		0.69 (0.45, 1.06)	0.093	—	—
Missing	0/1	-	-	—	—
TV at Home					
Yes	122/1142	1.00	-	—	—
No	27/343	0.71 (0.46, 1.10)	0.130	—	—
Missing	0/1	-	-	—	—
Where Watch TV					
Own home	123/1117	1.00	-	—	—

Someone else's home	15/203	0.64 (0.37, 1.13)	0.123	—	—
Missing	11/166	0.57 (0.30, 1.09)	0.088	—	—
TV hours watched daily	1486	0.995 (0.989, 1.001)	0.155	—	—
Sport Participation					
Yes	65/785	1.00		1.00	
No	84/701	1.51 (1.07, 2.12)	0.018	1.44 (1.02, 2.03)	0.038

Body fatness, as defined by body fat-for-age McCarthy 2006 reference

When exploring the association of the lifestyle variables with body fat status (overfatness), *Frequency of water collection, School Travel and Sport Participation* all displayed a significant association with being classified as overfat (Table 8-15). A decreased frequency of water collection led to increased risk of overfatness. The trend for *School Travel* and *Sport Participation* was the same as for the BMI-for-age references with walking to school having a decreased risk of overfatness vs using a motor vehicle and no sport participation resulting in increased risk compared to reporting participation. Other trends to note in this category were similar to that for Cole 2007/IOTF 2000, in that having no electricity at home, no TV at home and watching TV at someone else's home, as opposed to in your own home, all led to a slightly decreased risk of being classed as overfat, however, none of these observations reached significance.

Table 8-15 Univariable and multivariable regression analysis of lifestyle variables to analyse risk of overfatness, as defined by McCarthy 2006 body fat for age reference

			Body Fat		
Characteristic	**Events (Total)**	**Unadjusted OR**	**P Value**	**Adjusted OR**	**P Value**
Collect Water					
Yes	177/1265	1.00	-	—	—
No	33/251	0.93 (0.62, 1.39)	0.723	—	—
Frequency of Water Collection					
At least once a day	108/849	1.00	-	1.00	-
2-6 times a week	57/325	1.46 (1.03, 2.07)	0.034	1.48 (1.04, 2.12)	0.029
Once a week	11/64	1.42 (0.72, 2.81)	0.308	1.48 (0.75, 2.95)	0.259
Missing	34/278	0.96 (0.63, 1.44)	0.831	0.95 (0.63, 1.44)	0.807
Time taken to collect water (one way)	1516	0.99 (0.99, 1.00)	0.698	—	—
School Travel					
Motor Vehicle	54/244	1.00	-	1.00	-
Walk	153/1265	0.48 (0.34, 0.68)	<0.0001	0.51 (0.36, 0.73)	<0.0001
Bicycle	1/2	3.52 (0.22, 57.18)	0.377	3.44 (0.21, 56.18)	0.386
Missing	2/5	2.35 (0.38, 14.4)	0.357	2.48 (0.4, 15.35)	0.327
Time taken to travel to school	1516	1.00 (0.997, 1.00)	0.875	—	—
Electricity at Home					
Yes	167/1152	1.00	-	—	—
No	43/363	0.79 (0.55, 1.13)		—	—
Missing	0/1	-	-	—	—
TV at Home					
Yes	164/1160	1.00	-	—	—
No	46/355	0.90 (0.64, 1.28)	0.573	—	—
Missing	0/1	-	-	—	—

Where Watch TV					
Own home	164/1134	1.00	-	—	—
Someone else's home	29/211	0.94 (0.62, 1.44)	0.785	—	—
Missing	17/171	0.65 (0.39, 1.11)	0.113	—	—
TV hours watched daily	1516	0.996 (0.991, 1.001)	0.144	—	—
Sport Participation					
Yes	93/801	1.00	-	1.00	-
No	117/715	1.49 (1.11, 2.00)	0.008	1.42 (1.06, 1.92)	0.021

Mid-upper arm circumference (MUAC) analysed as a continuous variable measured in centimetres (cm)

The aim of this analysis was to examine risks associated with a high MUAC.

Factors found to have a significant effect on MUAC measurement were *Collecting Water, Frequency of Water Collection, Time Taken to Collect Water, Travel to School, Time Taken to Travel to School.*

Table 8-16 Univariable and multivariable regression analysis of lifestyle variables to analyse risk of high MUAC

	MUAC			
Characteristic	**Unadjusted Coefficient**	**P Value**	**Adjusted Coefficient**	**P Value**
Collect Water				
Yes	Reference		Reference	
No	1.39 (0.85, 1.92)	<0.0001	-2.66 (-5.86, 0.53)	0.103
Frequency of Water Collection				
At least once a day	Reference		Reference	
2-6 times a week	-0.64 (-1.15, -0.14)	0.013	-0.66 (-1.16, -0.16)	0.010
Once a week	-0.78 (-1.79, 0.22)	0.126	-0.72 (-1.72, 0.27)	0.154
Missing	0.99 (0.46, 1.53)	0.000	-0.99 (-2.48, 0.50)	0.193
Time taken to collect water (one way)	0.002 (0.001, 0.002)	<0.0001	0.005 (0.002, 0.008)	0.002
School Travel				
Motor Vehicle	Reference		Reference	
Walk	0.79 (0.24, 1.33)	0.005	0.7 (0.16, 1.24)	0.011
Bicycle	-3.03 (-8.57, 2.51)	0.284	-3.18 (-8.63, 2.28)	0.254
Missing	5.44 (1.92, 8.97)	0.002	3.18 (-0.50, 6.85)	0.090
Time taken to travel to school	0.007 (0.003, 0.01)	0.001	0.007 (0.003, 0.01)	0.001
Electricity at Home				
Yes	Reference	-	—	—
No	0.06 (-0.41, 0.54)	0.788	—	—
Missing	3.17 (-4.67, 11.02)	0.428	—	—
TV at Home				
Yes	Reference	-	—	—
No	0.05 (-0.43, 0.52)	0.842	—	—
Missing	3.02 (-4.83, 10.86)	0.451	—	—
Where Watch TV				
Own home	Reference	-	—	—

Someone else's home	0.19 (-0.39, 0.78)	0.517	—	—
Missing	0.09 (-0.55, 0.73)	0.787	—	—
TV hours watched daily	0.0008 (-0.006, 0.007)	0.823	—	—
Sport Participation				
Yes	Reference	-	—	—
No	0.17 (-0.23, 0.57)	0.410	—	—

Stunting, as defined by height-for-age WHO 2007 reference

This analysis was also run for stunting, however, no variables were statistically significant and so this analysis is not shown here. The lack of any significant findings may be expected, given that stunting is likely to be the result of early life programming and therefore day-to-day lifestyle factors later in childhood and adolescence may have little effect (Cameron et al., 2005a, Cameron et al., 2005b).

8.2.1 Discussion of analysis to investigate association between anthropometric measures and subjects response to the lifestyle questionnaire

Main findings

Analysis of an association between weight status and reported lifestyle factors found that *School Travel* and *Sports Participation* were both found to be significantly associated with BMI, using both WHO and Cole/IOTF references, where walking to school (i.e. active commuting) and participating in sport both resulted in a lower risk of being overweight.

The results were similar for body fat with active school travel and sport participation both showing a lower risk of being classed as overfat. An additional variable also found to display a significant effect on body fat was frequency of water collection with more frequent collection of water associated with lower risk of being classed as overfat.

Factors which showed an effect on MUAC were those related to water collection (whether collection was carried out, how frequently and the time taken to collect water) and travel to school (method of travel and time taken).

The analysis of stunting found no variables to have a significant effect on stunting.

Implications

The results of the present study infer that the aspects of lifestyle which may be important for future inclusion in overweight and obesity interventions would be increasing levels of active commuting and participation in sport, as a means to decreasing risk of overweight and obesity.

Comparison with other studies

The concept of examining specific daily activities and their relation to anthropometric outcome is an under-researched area, with the more common approach being to look specifically at physical activity as a whole, i.e., total volume or contribution of different intensities rather than on individual tasks performed (physical activity, both volume and intensity will be discussed in the following section).

To the author's knowledge no study has examined the effect of water collection on anthropometric status and given that this is a task primarily undertaken in low and middle income countries it is a factor not applicable to studies carried out in developed countries. Presence of electricity is another factor which would generally not be analysed as a risk factor in developed countries, given that electricity access is universal in these areas.

To the author's knowledge there are no studies available from developing countries where the aim was to assess associations between active commuting and weight status. Several recent studies carried out in developed countries, including the US, have tested associations between active commuting and weight status. Mendoza et al found active commuting was inversely associated with BMI z-score as well as skinfolds (Mendoza et al., 2011b) and two more recent studies both found active commuting to have a significant inverse association with obesity (Drake et al., 2012, Carter, 2012). Drake et al found those who actively commuted >3.5 days of the week were 33% less likely to be obese (Drake et al., 2012) while Carter et al estimated that obesity prevalence would decrease by 22.1% if all adolescents walked or cycled on at least 4 days per week (Carter, 2012). These three studies were all conducted in the US and therefore their generalisability to low and middle income countries is unknown.

However, one systematic review of active commuting, physical activity and weight found that of the 18 studies which assessed the association between active commuting and weight only three showed consistent results and therefore the authors suggest there may be no association between the two (Lee et al., 2008). A more recent study also found no association (Baig et al., 2009). Lack of consistency in results suggests the need for further studies.

As well as active commuting the studies by Carter et al and Drake et al also looked at the effect of sport participation on weight status (Carter, 2012, Drake et al., 2012). Carter et al found participation in team sports was inversely associated with both overweight and obesity and also with obesity as an independent outcome. Drake et al also found an inverse association between sport participation and weight status and estimated that obesity prevalence would decrease by as much as 26.1% if all adolescents played on two sports teams each year. Basterfield et al (in press) carried out a longitudinal study on English children (enrolled in Gateshead Millenium Study) at ages 7, 9 and 12 years to assess the longitudinal association between sport participation, fat mass and objectively measured physical activity. Results showed an inverse relationship between participation in sport and fat mass and the authors suggest preventing dropout from sports during adolescence should be made a high priority as an obesity prevention strategy. All the above mentioned studies were conducted in developed countries and therefore the results may not be generalisable to a low - middle income setting.

A large cross-sectional study of 2,200 adolescents from 10 European cities aimed to assess the link between television viewing and obesity risk and found television viewing (during mealtimes, in the bedroom and during weekend days) to be positively associated with obesity risk (Rey-Lopez et al., 2012).

A randomly selected sample of 11,658 Canadian children and adolescents age 5 - 19 years were enrolled in a study where parental reported height, weight and TV viewing between school and dinner time were used to determine association between TV and anthropometric outcome (Tudor-Locke et al., 2011). Results showed odds of being obese increased by 21% for every 30 minutes of TV watching, while odds of being overweight increased by 8% for every 30 minutes .

Another study conducted in 1,140 Cypriot children, mean age 10 years, found a significant gender difference in risk of TV viewing (Lazarou and Soteriades, 2010). Girls who watched more than four hours of TV/DVD per day were three times more likely to be overweight or obese and have a waist circumference (WC) >75th percentile and were 3.5 times more likely to have a body fat >30%. However, analysis in the boys found no significant associations (Lazarou and Soteriades, 2010).

Again the majority of studies investigating the link between TV viewing and weight status have been conducted in developed countries with little or no data available from low and middle income countries.

Strengths and limitations of present study to assess associations between anthropometry and reported lifestyle

There is a lack of evidence on the relationship between lifestyle activities and weight status especially in low and middle income countries. This study provides valuable information on an under-researched topic in an under-researched population. Interestingly a significant gender difference was highlighted in the data on TV viewing and therefore it may be beneficial for future studies to further investigate the effect of gender on this sedentary activity within this population. The cross-sectional design of the present study was a limitation and future studies on the same individuals may be beneficial in order to gain longitudinal data.

Conclusion

Active commuting, sport's participation and TV viewing may all be important factors in the development of overweight and obesity amongst children and adolescents and further research needs to be conducted in this area, especially within low and middle income countries, while interventions to tackle overweight and obesity should take these factors into account.

8.3 Sub-sample study results of exploratory analysis of association between physical activity/diet and weight status/body fatness

This section includes only those individuals who took part in the sub-sample study which involved objective physical activity assessment by accelerometry and dietary intake assessment by interviewer-administered 24 hour dietary recall. Given the small sample size this section deals with the exploratory analysis of associations between physical activity (energy expenditure) and diet (energy intake) measures and the possible risk associated with an individual's weight status or body fatness.

For the purposes of the analyses, individuals are defined as either overweight/not overweight where weight status is concerned (for both BMI references: WHO and Cole/IOTF) or overfat/not overfat (McCarthy body fat reference) where body fatness is concerned. To clarify, overweight includes both overweight and obese and not overweight includes both underweight and healthy, similarly overfat includes both overfat and obese and not overfat includes both underfat and healthy. Analysis was also carried out on height-for-age data classified as stunted or not stunted.

Weight status, as defined by BMI-for-age WHO 2007 reference (Table 8-17)

Physical activity

There was a significant difference in % time spent in both sedentary and light intensity activity between not overweight and overweight individuals; this was true for both accelerometry cut points used (Puyau and Evenson (Trost et al., 2010)), with overweight individuals spending a higher percentage of time sedentary and a lower percentage in light intensity activity. The % time spent in moderate-vigorous physical activity (MVPA) was lower in the overweight children using both Puyau and Evenson cut points, however, this did not reach significance. Overweight children also displayed significantly lower counts per minute (volume of activity), both single and integrated axes when compared to not overweight children.

Dietary energy intake

There was no significant difference in total energy consumption (kJ) between the overweight and not overweight participants, however, when looking at the results adjusted for their weight (kJ per kg) the overweight participants reported consuming significantly less energy than their not overweight counterparts.

Table 8-17 Physical activity and diet-related measures and their association with weight status, as defined by BMI-for-age WHO 2007 reference

	WHO – Median (IQR)		
Variable	**Not overweight***	**Overweight***	**P-value(*<0.05)**
Physical Activity (n)89	**73**	**16**	
Puyau Mean % Sed[1]	61.3 (54.3, 72.3)	71.8 (63.0, 77.4)	0.0103*
Puyau Mean % Light[2]	37.2 (26.8, 44.0)	26.1 (21.8, 35.5)	0.0076*
Puyau Mean % MVPA[3]	1.1 (0.5, 1.7)	0.7 (0.5, 0.9)	0.1114
Evenson Mean % Sed[1]	22.8 (15.5, 29.6)	29.5 (25.6, 37.0)	0.0053*
Evenson Mean % Light[2]	71.1 (63.8, 75.9)	67.5 (58.9, 70.7)	0.0177*
Evenson Mean % MVPA[3]	4.8 (2.4, 6.5)	3.2 (2.3, 5.7)	0.3471
Single Mean cpm[4]	783.1 (596.5, 902.3)	633.6 (487.5, 751.4)	0.0210*
Integrated Mean cpm[4]	1463.3 (1214.6, 1707.6)	1287.9 (989.7, 1464.2)	0.0285*
Diet *Full sample (n)* ***116***	**98**	**18**	
Energy kJ	7125.1 (5649.1, 8473.8)	7130.9 (6312.6, 7936.6)	0.8908
kJ/kg	210.6 (147.1, 276.0)	139.0 (107.6, 190.3)	0.0005*
Those who completed physical activity and diet (n) ***89***	**73**	**16**	
Energy kJ/day	7071.9 (5566.5, 8473.8)	6948.8 (6300.6, 7870.8)	0.8475
Energy kJ/kg/day	224.4 (151.2, 280.9)	130.6 (94.7, 174.5)	0.0003*

* Not overweight includes both underweight and healthy weight. Overweight includes both overweight and obese.
[1]Sed = Sedentary [2]Light= Light Physical Activity [3]MVPA=Moderate-Vigorous Physical Activity
[4]cpm=Counts per minute

Weight status, as defined by BMI-for-age Cole2007/IOTF 2000 Reference(Table 8-18)

Physical activity

Using the Puyau reference % time sedentary, % time light and % time MVPA were all significantly different between overweight and not overweight individuals with % time spent sedentary higher for overweight individuals but % time in light and MVPA lower. The same trend was shown for % time in each activity using the Evenson cut point, however, this reached significance for the sedentary and light data only and not for MVPA. Similar to the WHO data, overweight children also displayed significantly lower counts per minute both single and integrated, when compared to children who were not overweight.

Dietary energy intake

With regards to energy intake there was no significant difference in total energy consumption (kJ) between the overweight and not overweight participants, however, when looking at the results adjusted for their weight (kJ per kg) the overweight participants reported consuming significantly less than their not overweight counterparts with median intake for overweight participants being only around 50-60% of that reported by not overweight individuals.

Table 8-18 Physical activity and diet-related measures and their association with weight status, as defined by BMI-for-age Cole 2007/IOTF 2000 reference

IOTF – Median (IQR)			
Variable	**Not overweight***	**Overweight***	**P-value (*<0.05)**
Physical Activity(n) 85	**72**	**13**	
Puyau Mean % Sed[1]	61.2 (53.7, 72.0)	72.7 (62.8, 76.7)	0.0119*
Puyau Mean % Light[2]	37.2 (27.0, 44.0)	25.6 (22.3, 35.9)	0.0090*
Puyau Mean % MVPA[3]	1.2 (0.5, 1.8)	0.6 (0.4, 0.8)	0.0479*
Evenson Mean % Sed[1]	22.7 (15.2, 28.2)	29.5 (26.0, 34.1)	0.0046*
Evenson Mean % Light[2]	71.2 (66.8, 76.1)	67.3 (59.1, 70.8)	0.0210*
Evenson Mean % MVPA[3]	5.1 (2.7, 6.7)	3.2 (1.4, 4.8)	0.1873
Single Mean cpm[4]	790.6 (609.9, 903.8)	598.0 (490.2, 718.0)	0.0123*
Integrated Mean cpm[4]	1488.8 (1225.7, 1713.0)	1273.8 (990.0, 1392.1)	0.0184*
Diet *Full sample (n)**112***	**98**	**14**	
Energy kJ	7125.1 (5656.5, 8507.9)	7051.1 (6288.5, 7936.6)	0.8328
kJ/kg	216.7 (151.2, 276.0)	130.6 (107.6, 150.8)	0.0003*
Those who completed physical activity and diet (n) ***89***	**72**	**13**	
Energy kJ/day	7036.5 (5607.9, 8517.0)	6841.5 (6288.5, 7807.4)	0.7324
Energy kJ/kg/day	227.7 (163.3, 282.5)	124.5 (107.6, 149.5)	0.0001*

* Not overweight includes both underweight and healthy weight. Overweight includes both overweight and obese.
[1]Sed = Sedentary [2]Light= Light Physical Activity [3]MVPA=Moderate-Vigorous Physical Activity
[4]cpm=Counts per minute

Body fatness, as defined by body fat-for-age McCarthy 2006 reference (Table 8-19)

Physical activity

For the body fat reference there was a highly significant difference between overweight and not overweight individuals for all three intensities of activity by both cut points and for both categories of counts per minute; with overweight individuals having significantly higher % time spent sedentary but significantly lower light, MVPA and cpm (both single and integrated).

Dietary energy intake

For the dietary data the same applied as for the WHO and Cole/IOTF references, with no significant difference in overall reported energy consumption but a significant difference between reported energy per kg (kJ/kg).

Table 8-19 Physical activity and diet-related measures and their association with body fatness, as defined by body fat-for-age McCarthy 2006 reference

	Body Fat –Median (IQR)		
Variable	**Not Overfat***	**Overfat***	**P-value (*<0.05)**
Physical Activity (n)89	**71**	**18**	
Puyau Mean % Sed[1]	61.3 (53.2, 72.0)	75.9 (63.3, 81.4)	0.0002*
Puyau Mean % Light[2]	37.2 (27.2, 44.0)	23.9 (18.5, 35.9)	0.0002*
Puyau Mean % MVPA[3]	1.3 (0.6, 1.8)	0.6 (0.2, 0.8)	0.0010*
Evenson Mean % Sed[1]	22.8(16.4, 28.3)	33.8 (26.0, 40.0)	0.0016*
Evenson Mean % Light[2]	71.1 (66.7, 75.7)	64.3 (58.6, 70.8)	0.0123*
Evenson Mean % MVPA[3]	5.4 (2.7, 6.9)	3.1 (1.1, 4.7)	0.0041*
Single Mean cpm[4]	794.1 (611.4, 905.3)	536.1 (414.9, 701.3)	0.0004*
Integrated Mean cpm[4]	1494.9 (1236.8, 1718.4)	1191.5 (857.9, 1338.3)	0.0009*
Diet *Full sample* *(n)* ***117***	**95**	**22**	
Energy kJ/day	7013.6 (5649.2, 8473.8)	7449.9 (6288.5, 8233.2)	0.5031
Energy kJ/kg/day	203.6 (142.8, 275.0)	145.2 (107.6, 198.1)	0.0068*
Those who completed physical activity and diet *(n)* ***89***	**71**	**18**	
Energy kJ/day	6962.7 (5566.5, 8473.8)	7449.9 (6288.5, 8083.4)	0.6024
Energy kJ/kg/day	224.4 (151.2, 276.6)	130.6 (102.9, 196.0)	0.0010*

* Not overfat includes both underfat and healthy weight. Overfat includes both overfat and obese.
[1]Sed = Sedentary [2]Light= Light Physical Activity [3]MVPA=Moderate-Vigorous Physical Activity
[4]cpm=Counts per minute

Relationship of stunting (defined by WHO 2007 height-for-age) with physical activity and dietary measures (Table 8-20)

There was little difference between the physical activity and dietary results for stunted and not stunted individuals. The only significant results were a higher MVPA for stunted individuals compared to not stunted individuals when using the Evenson cut point and also a higher integrated cpm. There was no significant difference between dietary measures.

Table 8-20 Physical activity and diet-related measures and their association with stunting status, as defined by height-for-age WHO 2007 reference

STUNTING – Median (IQR)			
Variable	**Not Stunted**	**Stunted**	**P-value(*<0.05)**
Physical Activity (n) 89	**78**	**11**	
Puyau Mean % Sed[1]	63.6 (56.3, 74.0)	59.0 (50.9, 66.2)	0.0788
Puyau Mean % Light[2]	35.0 (25.2, 42.1)	40.4 (32.8, 44.4)	0.1078
Puyau Mean % MVPA[3]	1.0 (0.4, 1.6)	1.4 (1.0, 3.8)	0.0999
Evenson Mean % Sed[1]	25.0 (17.9, 34.9)	23.0 (18.1, 25.0)	0.2314
Evenson Mean % Light[2]	70.1 (63.2, 74.8)	71.8 (63.8, 78.2)	0.3563
Evenson Mean % MVPA[3]	4.2 (2.3, 6.4)	5.9 (4.8,10.7)	0.0503*
Single Mean cpm[4]	727.8 (525.2, 859.9)	800.8 (686.6, 1032.6)	0.1051
Integrated Mean cpm[4]	1390.4 (1142.1, 1599.3)	1702.6 (1362.9, 1790.0)	0.0248*
Diet			
*Full sample (n)**116***	**103**	**13**	
Energy kJ/day	7178.4 (5773.5, 8472.1)	6962 (6276.2, 7807.4)	0.8576
Energy kJ/kg/day	181.8 (141.0, 261.0)	230.2 (136.6, 280.9)	0.4596
Those who completed physical activity and diet (n) ***89***	**78**	**11**	
Energy kJ/day	7036.5 (5649.2, 8233.2)	6962.7 (6276.2, 9185.6)	0.78
Energy kJ/kg/day	197.0 (141.4, 261.9)	230.7 (136.6, 300.7)	0.36

* Stunted includes all individuals who had height for age z-scores <-2. Not stunted includes all other individuals.
[1]Sed = Sedentary [2]Light= Light Physical Activity [3]MVPA=Moderate-Vigorous Physical Activity [4]cpm=Counts per minute

MUAC

Given that MUAC was displayed as a continous variable and there were no cut points available it was not possible to display results according to MUAC

8.3.1 Discussion of exploratory analysis investigation association between physical activity and diet-related measures and anthropometric status

Main Findings

In the present exploratory analysis there were significant differences in physical activity and dietary measures between overweight/overfat and not overweight/not overfat individuals.

BMI measured by Cole/IOTF and body fat measured using the McCarthy reference both found significantly higher % time sedentary and lower % time in both light and MVPA activity in the overweight/overfat individuals. BMI measured using the WHO reference also found significant differences but only for % time sedentary and light, with no significant difference between % time in MVPA for this reference. Total volume of activity measured by counts per minute was lower in overweight/overfat individuals using all measures BMI (both WHO and Cole/IOTF) and body fat (McCarthy et al., 2006).

While there was not a significant difference in total energy consumed there was a significant difference in weight-adjusted intake (kJ per kg) with overweight/overfat individuals reporting significantly less energy per kg than their not overweight/not overfat counterparts for all references (BMI - WHO and Cole/IOTF and body fat - McCarthy).

There was little difference between physical activity and the diet of stunted and non stunted individuals and this may be in line with current evidence suggesting stunting is predicted more by programming in early life than by daily lifestyle habits.

Implications

The higher levels of time spent sedentary and lower levels of time spent active in either light or moderate - vigorous activity may be an important risk factor for the increased levels of overweight and overfatness amongst subjects in this sample. However, this was a very small exploratory study and therefore a larger study may be necessary to confirm these assumptions. Further the association may be bi-directional, for example, in some instances overweight and overfatness may precede a decrease in physical activity rather than being a result of low levels of physical activity (Bauman et al., 2012, Ekelund et al., 2011).

The significant difference found in weight-adjusted energy intake may support the theory of higher levels of misreporting in overweight and overfat individuals.

Further analyses was not carried out on stunting data, given the exploratory nature of this small study and the fact that stunting was not a major aim of investigation in the present study. The lack of association between stunting and physical activity/energy intake was to be expected given that stunting is likely to be programmed in early childhood, at an age younger than the children recruited in this study.

Comparison with other studies

A systematic review by Rauner et al of studies published since the year 2000, found an inverse relationship between physical activity and overweight (including obesity) in adolescents aged 11 - 23 years, however the review concluded with a call for further studies to investigate the direction of causality between the two factors which is as yet unclear (Rauner et al., 2013).

Similar to the results of the present study a study of 5,890, 11 - 16 year old Canadian adolescents found overall physical activity levels were significantly lower in overweight and obese participants than in those who were classed as normal weight (Janssen et al., 2004). A further study by Janssen et al included 137,593 adolescent aged 10 - 16 years from 34 countries (primarily European) and a comparison of overweight and obesity was made with physical activity and diet, results again showed that in the majority of countries physical activity levels were lower in overweight individuals compared to their counterparts classed as normal weight (Janssen et al., 2005).

A study conducted in England looked at the effect of different intensities of physical activity on adiposity in 403 children aged 7 - 9 years and found that MVPA was inversely associated with fat mass and BMI z-score in boys but not in girls. Contrary to the present study Basterfield et al found there was no association between time spent sedentary and BMI z-score (Basterfield et al., 2012a).

A recent paper published in the Lancet as part of a physical activity series suggests the need for further studies examining the determinants of physical activity, including directionality of effect (Bauman et al., 2012), and for studies to take an ecological approach in assessing the effect of both individual and higher level influences. The effect of individual and community level factors on participation in physical activity has also been noted elsewhere (Yang et al., 2012).

Several studies have already aimed to investigate possible predictors of physical activity (Graham et al., 2012, Seabra et al., 2012, Verloigne et al., 2012, Verloigne et al., 2013) and factors highlighted include self efficacy, receiving support from friend and teachers, enjoyment of participation in vigorous physical activity, acceptance by peers when playing games and sports, parental encouragement and perceived physical competence (Graham et al., 2012, Seabra et al., 2012). A systematic review on this subject (Verloigne et al., 2012) found the most important correlates of physical activity in young people aged 10 - 12 years were taking part in physical activity with parents, parental and maternal level of physical activity and level of support received from parents (Verloigne et al., 2012).

Given the significant association found in the present study between low levels of activity (both intensity and volume) and risk of overweight it would be extremely beneficial to be able to pinpoint the reason behind this lack of activity in order to allow potential barriers to physical activity to be reduced or removed and more effective interventions to be developed.

Several South African studies have looked at the total energy intake of children and adolescents (Labadarios et al., 2005, Faber et al., 1999, Rankin et al., 2011b) or their dietary habits (Feeley et al., 2012, Feeley et al., 2013), however, few of these have used weight-adjusted intake to look at the association between energy intake and anthropometric status. Given that weight-adjusted intake was the variable found to be significantly associated with weight and fat status in the present sample, results are not directly comparable to previous South African studies and therefore there is a need for further dietary assessment studies in this area which look at the effect of diet on anthropometric status.

Strengths and weaknesses

This was a small exploratory study, however, there is a lack of studies investigating the effect of physical activity and diet on weight status in low and middle income countries, therefore this study provides valuable preliminary data.

Conclusions

Results of this exploratory analysis suggest increased MVPA and reduced sedentary behaviour may have a beneficial effect on weight status. Future studies should investigate this effect in order to inform the development of effective interventions to tackle the emerging obesity epidemic in resource-poor settings.

The lower levels of weight-adjusted energy intake found in the overweight individuals in the present sample may have been a function of misreporting rather than of genuinely lower intakes. For this reason care should be taken when analysing dietary data and results should be presented as weight-adjusted intake in order to bring to light any evidence of underreporting.

Further studies are needed to investigate the correlates of physical activity in this population in order to allow appropriate action to be taken to remove or reduce current barriers to participation in physical activity.

9 Final discussion and conclusions

This chapter will summarise the key findings of the present study, presented in relation to the initial hypotheses, and provide an overview of the main strengths and limitations. Suggestions of potential policy implications from the present study and recommendations for future research will then be discussed.

9.1 Key Findings

9.1.1 Prevalence of overweight and obesity

Hypothesis: *The prevalence of overweight and obesity in this population increases with age, from 3-10% to 25-50% at 7 and 15 years respectively, as defined by Cole's standards (Cole et al., 2000).*

Findings: Prevalence of overweight (defined by both BMI (WHO and Cole/IOTF) and overfat (McCarthy)) was higher in girls than boys and increased with age in girls. In boys, prevalence of overweight increased slightly with age, however, prevalence of overfat decreased with age. Using the Cole/IOTF BMI for age reference combined overweight and obesity in girls was 8% in grade 1 compared to 23% in grade 9 ($p<0.01$) and for boys it was 3% in grade 1 and 6% in grade 9 (p 0.65) (see Chapter 5: Prevalence).

Implications: The present study provides evidence that overweight is an issue in children and adolescents in this rural area of South Africa, in particular amongst girls, and suggests the need for future surveillance to track the course of this. Further, it suggests that there are at least potential benefits of using a simple body fat measure.

There is a possibility that the prevalence noted here was affected by factors which were not measured in this study such as pubertal development. There is evidence to show that prevalence of overweight and obesity may increase in females during puberty and that may be one explanation for the results we have found here. This increase is believed to be a function of both physical changes (changes in fat distribution)(Taylor et al., 2010) and environmental changes (reduction in physical activity)(Goran et al., 1998, Davison et al., 2007). Males in the present study displayed a lower prevalence of overweight and obesity compared to the females, one explanation may be that males generally reach puberty at a later age than females and therefore it is possible that the males in this study have not yet reached puberty and therefore prevalence of overweight and obesity will increase at a later stage. An alternative explanation is that early stunting has been linked to overweight in later life (Victora et al., 2008) and therefore the combination of both physical and environmental changes could be the cause in this instance. Therefore it could be that despite the high levels of stunting in males during the early years, which may be expected to increase obesity risk, the maintenance of physical activity throughout adolescence is a protective factor whereas in the females both physical and environmental changes occur. It is hard to tell given that we only have child and adolescent prevalence here and it would be useful to follow up these individuals over time to track change in weight status.

There appears to be a strong cultural acceptance of overweight /obesity, and future community-wide education may be warranted to tackle the belief that overweight indicates health and wealth and is therefore desirable.

There is a delicate balance between over- and undernutrition and in many cases the two can be witnessed within the same household (Steyn et al., 2005, Kolcic, 2012, Kimani-Murage, 2013), creating an additional complication when attempting to design future interventions.

9.1.2 Correlates of overweight and obesity

Hypothesis: *The strength of the association of household and community variables with risk for overweight and obesity varies with age; for girls <11 years the dominant factor is distance to nearest water supply; for girls >11 years and boys of any age, distances to nearest road or school dominate.*

Findings: Of all individual, maternal, social and economic determinants analysed, sex and school grade (age) were the only two consistently shown to be significant predictors of overweight status: females and individuals in a higher school grade (i.e., grade 9) were at increased risk of overweight (see Chapter 8: Correlates). Specifically, the distance to water supply and the nearest road or school were not associated with overweight status.

Implications: Despite an in depth analysis of many variables, from the present results it appears females in the oldest age groups should be the target of interventions. However it is possible that the present study failed to investigate risk factors that are important in this setting (e.g. sleep duration, pubertal status, psychological status), therefore future studies should investigate additional factors in order to determine whether they are responsible for increasing or decreasing risk.

9.1.3 Sub-sample study of physical activity and diet

Hypothesis: *Data loss as well as reliability and stability of collected data will be of inferior quality to that in a matched western population.*

Findings: Physical activity and dietary assessment measures were well accepted and feasibility of using these measures within this population was good and of a similar standard to those in western populations (see Chapter 7: Lifestyle, physical activity and diet).

Implications: These results imply that these particular measures of diet and physical activity could be used again in this population and that the results produced are of a similar validity to those in western settings.

9.1.3.1 Physical Activity

Primary hypothesis*: Even within this rural population, heterogeneity in physical activity will be considerable; 25% of children from relatively wealthy, peri-urban, households have physical activity levels less than the recommendations for the developed world (60 minutes moderate - vigorous intensity physical activity (MVPA) per day) at all ages (no comparable South African studies exist and therefore this hypothesis was based on data from the Scottish Health Survey which found that 75% of similar age groups in Scotland achieve physical activity recommendations when assessed by questionnaire).*

Findings: The sample recruited displayed a higher total volume of activity but at a lower intensity than children and adolescents in developed countries. Depending on cut point used few or no study participants achieved international recommendations of 60 minutes per day of moderate - vigorous physical activity every day (see Chapter 7: Lifestyle, physical activity and diet).

Implications: Physical activity levels in the present study were higher than expected in terms of volume but there was a lack of MVPA. These results (high volume, low intensity) raise the question as to whether current international physical activity guidelines (60 minutes MVPA per day) are appropriate for all children and adolescents globally and whether it is only intensity which matters. If MVPA is necessary for many health benefits then future interventions may need to focus on MVPA which, in turn, might mean targeting leisure time activity and increasing the availability of sporting activities in schools. This is a behaviour affected by culture and therefore community-wide education may be warranted to increase knowledge of its importance.

9.1.3.2 Diet

Hypothesis: *Estimate dietary underreporting will increase with age as reported in previous studies and be more prevalent in overweight/obese individuals (Rennie et al., 2005, Lioret et al., 2011, Lanctot et al., 2008). There may be evidence of older individuals having increased access to convenience foods outside the home.*

Findings: Energy intake was below recommended requirements (RDA). There was evidence of mis-reporting/underreporting and this was higher amongst individuals classed as overweight and those in the older age groups (see Chapter 7: Lifestyle, physical activity and diet). There was a possible trend for increased consumption of high fat, high sugar convenience food amongst those in the older age groups (see Chapter 7: Lifestyle, physical activity and diet).

Implications: There is a need to further investigate dietary intake data in this population to determine whether the underreporting noted is a function of misreporting or genuinely unphysiological intakes as a result of food insecurity.

As developing countries are affected by the nutrition transition, availability of energy-dense, high fat/sugar foods increases and there is a need for education about healthy eating to allow individuals to make informed choices. Food provided in schools should provide the best possible nutrients for increasing variety of diets and exposure to fruit and vegetables; taking into account that for some children this may be their only meal. These aspects should be incorporated into government strategies/policies and the current food programme running in South African schools.

9.1.4 Additional findings

Stunting

Stunting (height-for-age) was more prevalent in boys (16%, 14.2% and 15.3% in grades 1, 5 and 9 respectively) than in girls (13.6%, 6% and 4.5% in grades 1, 5 and 9 respectively) (see Chapter 5: Prevalence).

Implication: Stunting appears to be a considerable issue in this population, more so in boys than in girls. Interventions that target pregnant women may be beneficial given the effect early programming is believed to play on a child's height (Barker, 2004b, Dewey and Begum, 2011). The current study did not adjust for pubertal development and this may have affected results as discussed above in section 9.1.1.

Mid-Upper Arm Circumference

Analysis of mid-upper arm circumference (MUAC) data found only one individual was classed as severely malnourished by the current cut points. New MUAC cut points for potential use in defining overnutrition (overweight and overfatness) were developed (see Chapter 6: MUAC).

Implication: This study provides a proof of concept for the possible use of MUAC as an alternative, simple and inexpensive proxy measure for overweight/overfatness. Future studies should investigate this further to inform the potential development of an international reference.

Lifestyle Questionnaire

In response to the lifestyle questionnaire, the sample reported high levels of water collection, active commuting and TV watching (>70%). Participation in sport was low, especially in girls at the oldest age group.

Implications: These results imply physical activity is carried out as a necessity (i.e., household chores, travel to school) rather than as a leisure time activity (see Chapter 7: Lifestyle, physical activity and diet), while sedentary behaviour (screen time) was higher than may have been expected in this rural setting.

The present study suggests that levels of active commuting are already very high. Maintenance of this should be encouraged despite increases in development and therefore possible increased availability of motorised transport. This was the first active commuting survey in this population and therefore provides valuable public health surveillance data. Future surveillance is needed to determine whether this behaviour declines as community development and resources increase. A full description is beyond the scope of this thesis but there are several systematic reviews available which focus on secular trends in active commuting among children and adolescents (Lee et al., 2008, Drake et al., 2012).

South Africa is now involved in the Healthy Active Kids Programme, a scheme originally started in Canada whereby a report card is produced detailing the current health status of youth within a country in relation to factors such as physical activity, weight status, healthy eating, tobacco use and alcohol intake. In 2010 South Africa scored a C-, this grade is summarised as ‘good practice, limited reach and impact, moderate risk’ (Colley et al., 2012). Points highlighted as concerning in comparison to the 2007 report card were the decline in physical activity, physical education and increase in sedentary activity, and an increased prevalence of overweight, obesity and stunting. It is encouraging for South Africa to be a part of this scheme and have the ability to measure these factors as well as being able to highlight specific areas which require attention. In some other countries objective measures of physical activity are used in the report card but such data are not currently available for South Africa.

9.2 Strengths and limitations of the present study

Strengths:

This was the first assessment of overweight status in children and adolescents in this specific population but also within South Africa. In settings with a high prevalence of HIV, studies of this nature are very limited.

The present study conducted the first use of anthropometry in this population of children and adolescents as well as the first known use of bio-impedance amongst South African children and adolescents.

This study provided one of very few large scale studies which have collected MUAC data on children and adolescents and this is the first time MUAC has been analysed for its potential as a proxy for overweight/overfatness.

The sample recruited was representative of this area in terms of rural/urban status as well as the economic status of the school/surrounding community (as defined by school quintile) (see Chapter 4: Methods).

Although the study was not longitudinal in nature, the recruitment of children and adolescents from three different age groups allowed the assessment of differences between the ages.

The study was conducted within a demographic surveillance site (Africa Centre Demographic Surveillance Area) so a wealth of data regarding socio-economics, living conditions and family members were available on those young people who were matched to the database. This allowed multilevel analysis of the correlates of overweight and obesity.

An objective measurement of physical activity was used in the present study, such a method is now regarded as essential in aetiological studies of obesity (Reilly et al., 2008). Basterfield et al (Basterfield et al., 2008) have shown that self-report by questionnaire can result in a huge overestimation of those achieving recommendations and therefore does not provide as accurate results as objective measurement (see Chapter 2: Aims).

The 24 hour recall dietary assessment used in the present study is a validated technique in South African children and adolescents and up-to-date analysis software were also available (see Chapters 3, 4 and 7).

One group of fieldworkers conducted all data collection, received the same training and were observed during fieldwork (by the author). Each fieldworker was assigned a particular task which they performed for the duration. These measures ensured that both intra- and inter-observer variation were kept to an absolute minimum. The same equipment was used throughout the study (see Chapter 4: Methods).

Limitations:

The present study was cross-sectional as a result of the time and resources available (see Appendix 3); a longitudinal or series of cross-sectional studies would increase the strength of the data.

Puberty was not measured in the present study and given the impact puberty is believed to have on weight status this may have improved the study (He et al., 2002, Taylor et al., 2003, Taylor et al., 2010).

Given the rural setting of the present study and the resulting unreliable electricity connection it was necessary to use a portable, bio-impedance device. Therefore the ethnic specific body fat reference recently published by Haroun (Haroun et al., 2009b) could not be used as it requires use of the raw impedance value in ohms and this is only provided on mains powered devices. Use of this reference would have improved reliability and validity of data.

Although this study was indeed intended to be a small exploratory study of lifestyle with regards to diet and physical activity, data from the full sample rather than a sub-sample would have been advantageous.

Some individuals could not be matched to their demographic surveillance data; this could only have been improved by going home with every participant. Given the very limited funds on which this study took place this would not have been possible (see Appendix 3).

9.3 The present study in the context of current policies

There are many policies and goals currently in place which aim to tackle the long-standing nutritional problems of children and adolescents in low- and middle-income countries as well as the more recent epidemic of obesity and non-communicable diseases worldwide. These include the Millennium Development Goals (MDGs) (UN, 2002), Non-Communicable Disease (NCD) Control Agenda (NCD Alliance, 2013), WHO Obesity Strategy (WHO, 2011), Vienna Declaration on Nutrition and Non-Communicable Diseases in the Context of Health 2020 (WHO, 2013b) and the Toronto Charter on Physical Activity (Bull et al., 2010).

The present study was relevant to several of the MDGs (in particular 1, 4, 5 and 6. These goals relate to: 1 - eradicating extreme poverty and hunger, 4 - reducing child mortality, 5 - improving maternal health and 6 - combating HIV/AIDs, malaria and other diseases) and also provides evidence backing the proposal to include NCDs in any future development agendas published. South Africa has a unique structure in that it has both a sophisticated infrastructure and highly developed areas alongside large inequalities in both education and healthcare. For this reason its successes in achieving the MDGs are varied. South Africa has made the MDGs a high priority and has accepted the need for increased availability of statistics under the premise that if it cannot be measured it cannot be managed. In this instance the present study provides new data which will add to the current literature.

This study is in the context of the claims of the NCD alliance which state “NCDs are the most common cause of global death and disability, accounting for 54% of all disability and 63% of deaths worldwide...rising fastest in low- and middle-income countries (LMICs) and impacting disproportionately on disadvantaged communities” (NCD Alliance, 2013). This study also provides evidence on overweight/overfatness status and levels of physical inactivity, both precursors of NCDs in this rural population.

The findings provided by the present study will serve to inform the prevalence of overweight/overfatness in this under-researched population and to allow development of interventions in this area which would be in line with the WHO Obesity Strategy (WHO, 2011).

The present study indicates that individuals in this population are not achieving the international recommendations for 60 minutes moderate - vigorous physical activity. As physical inactivity is the fourth leading cause of chronic disease mortality (WHO, 2009d) these findings suggest that physical activity interventions are required and should follow the guidelines stated in the Toronto Charter on Physical Activity (Bull et al., 2010).

Interestingly, the recently published Vienna Declaration highlights childhood obesity as a target for the control of non-communicable diseases (WHO, 2013b). The detrimental effect which obesity has on quality of life as well as the wider economy is acknowledged and the report notes a promise to facilitate action to tackle overweight, obesity and undernutrition, particularly in children. The need for a society-wide approach is emphasised and the declaration calls for action from governments to develop policies which will make the healthy choice the easy choice (WHO, 2013b, Lawlor and Pearce, 2013).

9.4 Key recommendations arising from the present study

The UK MRC guidance should be followed in the development and evaluation of interventions (Craig et al., 2008). Interventions in South Africa may need to be population-wide or school-based as there is limited capacity for individual counselling within a public health system which is already stretched in dealing with chronic communicable diseases such as HIV and tuberculosis (TB). A recent systematic review of interventions in low- and middle-income countries found that school-based interventions had the potential to improve physical activity, diet and unhealthy weight status (Verstraeten et al., 2012). Another possibility which may be potentially useful is church-based interventions, an approach that has been used previously in the US, mostly amongst African Americans in areas where a large percentage of the population still attend church (Cowart et al., 2010, Thompson et al., 2013, Trost et al., 2009, Campbell et al., 2007). Approximately 56% of South Africans are reported to attend church, fourth highest amongst all countries, and so church-based interventions might be considered as a potential intervention pathway (World Values Survey, 2013). The potential for this technique is currently being explored amongst a sample of individuals in the Birth-to-Twenty cohort in South Africa (Rebecca Pradeilles, personal communication.)

9.5 Future research directions

Future intervention research should follow MRC guidance on the development and evaluation of complex interventions in public health (Craig et al., 2008).

Results from the present study suggest females in the older age groups would be the population group most at risk of overweight and obesity and therefore females may be the most appropriate target for future interventions, at a point before they become overweight.

The possibility of using MUAC as a simple proxy for overweight, obesity, and overfatness should be investigated further.

To date there has been very limited intervention research on physical activity in LMICs (and even less from sub-saharan Africa), as evidenced by the Lancet series 2012 (Hallal et al., 2012, Kohl et al., 2012); and equally limited intervention research on obesity prevention in children and adolescents in LMICs as evidenced by a systematic review by Verstraeten et al (Verstraeten et al., 2012).

A previous study carried out in a population of adults within the Africa Centre DSA found high levels of overweight amongst women (70.1% and 78.5% at ages 25-34 and 34-44 respectively) (Barnighausen et al., 2008). Investigation into what happens at puberty is important for informing both aetiological as well as intervention studies (Karlberg, 1989a, Cameron et al., 2009). The oldest participants in the present study will now be approximately 18 years of age and therefore will now have their height, weight, blood pressure and blood glucose routinely measured within the Africa Centre Demographic Information System (ACDIS); it may be interesting to follow this and track their change over time.

The present study did not focus on ‘how’ to intervene but rather on the scale of the problem within this particular setting; the hope would be that future research uses these findings to inform the development of future interventions.

The findings from similar studies throughout South Africa such as those from the Birth-to-Twenty cohort, the Agincourt DSA and other national surveys would all be useful resources.

'Train a child in the way he should go and when he is old he should not depart from it'

Proverbs 22:6

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