ANTHROPOMETRIC INDICATORS IN IDENTIFYING MALNUTRITION RISK AMONG CHILDREN YOUNGER THAN TWO YEARS IN MOTHERWELL, NELSON MANDELA METROPOLITAN MUNICIPALITY

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ANTHROPOMETRIC INDICATORS IN IDENTIFYING MALNUTRITION RISK AMONG CHILDREN YOUNGER THAN TWO YEARS IN MOTHERWELL, NELSON MANDELA METROPOLITAN MUNICIPALITY

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DECLARATION

In accordance with Rule G4.6.3, I, Shawn William McLaren (student number 215381912) hereby declare that this dissertation on the “Anthropometric indicators in identifying malnutrition risk among children younger than two years in Motherwell, Nelson Mandela Metropolitan Municipality” is my own work and that it has not previously been submitted for assessment to another University or for another qualification.

SIGNATURE:

DATE: 2016

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Abbreviations

AIDS	Acquired Immunodeficiency Syndrome
BMI	Body mass index
CCHIP	Community Childhood Hunger Identification Project
CI	Confidence interval
CP	Cerebral palsy
FAS	Foetal alcohol syndrome
GMP	Growth monitoring and promotion
HAZ	Height-for-age Z-score
HHFIS	Household food insecurity
HIV	Human immunodeficiency virus
HR	Hazard ratio
INP	Integrated nutrition programme
LBW	Low birth weight
MAM	Moderate acute malnutrition
MDGs	Millennium Development Goals
MUAC	Mid-upper arm circumference
NCHS	National Centre for Health Statistics
NFCS	National Food Consumption Survey
NMBHD	Nelson Mandela Bay Health District
NMMM	Nelson Mandela Metropolitan Municipality
OR	Odds ratio
RR	Relative risk
RtHB	Road to health booklet

RUTF	Ready to use therapeutic food
RVD	Retroviral disease
SAM	Severe Acute Malnutrition
SANHANES-1	South African National Health and Nutrition Examination Survey
SD	Standard deviation
T2 DM	Type 2 diabetes mellitus
TB	Tuberculosis
UNAIDS	The Joint United Nations Programme on HIV/AIDS
UNICEF	United Nations Children’s Fund
VAD	Vitamin A deficiency
WAZ	Weight-for-age Z-score
WFL	Weight-for-length Z-score
WFL	Weight-for-length Z-score
WHO	World Health Organisation
WHZ	Weight-for-height Z-score

Definitions

Height for age: An indicator of nutritional status based on an index involving a child's height and age. It is used to classify a child as stunted, severely stunted or growing normally. Height for age (HFA) is usually expressed in terms of the nearest Z-score standard deviation from the WHO standard.

Mid-upper arm circumference: Mid-upper arm circumference (MUAC) is a measure of nutritional status. It involves measuring the circumference of the arm between the shoulder and elbow, and comparing the measurement obtained to a known norm for age and sex. MUAC is usually expressed in centimetres (cm) to the nearest 0.1cm and can be termed absolute MUAC.

MUAC for age: MUAC for age (MAZ) is an index-based indicator of nutritional status. MAZ is directly age related, based on the expected MUAC for a given age compared with the WHO standard. It differs from absolute MUAC in that it is expressed in terms of standard deviations instead of centimetres.

Stunting: Condition of nutritional deficiency where a child has not met his or her linear growth potential. Moderate stunting is defined as a height for age Z-score (HFAZ) plotted below the -2 standard deviation (SD) line from the WHO reference, while severe stunting is defined as a HFAZ of less than -3 SD from the WHO reference (WHO and UNICEF, 2009). Stunting is sometimes also referred to as chronic malnutrition.

Underweight: Underweight for age is defined as a low weight for age, diagnosed using the growth chart. A weight for age Z-score (WFAZ) plotted below -2 SD from the WHO reference is classified as underweight for age, while a WFAZ plotted below the -3 SD line from the reference is classified as severely underweight for age (WHO and UNICEF, 2009).

Weight for age: An indicator of nutritional status based on an index involving a child's weight and age. It is used to classify a child as underweight for age, severely underweight for age or growing normally. Weight for age (WAZ) is usually expressed in terms of the nearest Z-score standard deviation from the WHO standard.

Weight for height: An index based on a child's weight and height used to determine whether the child is wasted or has an appropriate level of nutritional reserves. It is alternatively known as weight for length. Weight for height (WHZ) is usually expressed in terms of the nearest Z-score standard deviation from the WHO standard.

Wasting: Moderate wasting is classified as a weight for height Z-score (WFHZ) plotted below -2 SD of the WHO reference. Moderate wasting is also referred to as moderate acute malnutrition (MAM). Severe wasting, or severe acute malnutrition (SAM) is defined as a WFHZ plotted below -3 SD line on the WFHZ chart (WHO and UNICEF, 2009).

Abstract

Introduction: South Africa is burdened with a high prevalence of childhood malnutrition. The World Health Organisation (WHO) endorses weight for length (WFL) Z-scores and mid-upper arm circumference (MUAC) as tools for identifying children who are malnourished. The MUAC measurement offers many advantages for its use in community nutrition, and may aid in the early identification of malnourished children. More accurate and comprehensive data on child anthropometric status are needed in the Nelson Mandela Bay Health District (NMBHD), as well as assessment of the efficacy of using a simplified tool such as MUAC to screen for malnutrition.

Aim: This study aimed to synthesise a profile of the nutritional status of children younger than two years old in Motherwell, Nelson Mandela Metropolitan Municipality (NMMM) to assess the value of MUAC as a predictor of malnutrition risk and develop malnutrition screening recommendations relevant to this population.

Methods: This study followed a cross-sectional design using a quantitative approach. A convenience sample (n=419) of children below 24 months of age was selected from clinics and creches in Motherwell between October 2015 and February 2016 (Ethics approval: H15-HEA-DIET-002). Primary caregivers provided informed written consent for study participation. Trained fieldworkers performed anthropometric measurements according to standardised methods and completed a structured questionnaire. Data was described using means and standard deviations. Linear regression was used to assess relationships within the data. The MUAC's ability to identify malnutrition was described using sensitivity and specificity probabilities.

Results: Only 6% of the sample of children (n=23) were classified as stunted and 3% of the children (n=12) were severely stunted. The WHZ Z-score identified 0% (n=1) child with severe acute malnutrition (SAM), and 1% (n=3) children as MAM. The MUAC identified more children as SAM (2%) and MAM (3%). It was found that 16% of the children (n=65) were overweight or obese according to WHZ. It was found that there is a strong linear relationship between WHZ and MUAC (r=0.739). Using the least squares regression equation, a MUAC cut off value of 13,80cm for males and 13,5cm for females between six and 24 months old was projected. The

male cut-off value has a 100% sensitivity and 94,5% specificity for MAM and SAM while the female MUAC cut off had a specificity of 96,4%. Low birth weight children had significantly ($p<0.0005$) lower mean WAZ and HAZ scores than normal birth weight children.

Conclusions and recommendations

The prevalence of overweight and obesity among children younger than two years was high in Motherwell, while stunting and wasting prevalence were lower than expected for the population. Raising the MUAC cut-off values from 12,5cm for MAM to 13,80cm for males and 13,47cm for females may increase the number of children younger than two years who are included in nutrition interventions. It is recommended that healthcare workers focus on breastfeeding and appropriate complementary feeding practices to reduce the risk of overweight in infants and young children.

CHAPTER 1 INTRODUCTION AND PROBLEM SETTING

1.1 INTRODUCTION

Childhood malnutrition is a leading cause of under-five mortality across the developing world and is associated with 45% of all under-five child deaths (World Health Organisation, 2013). Severe Acute Malnutrition (SAM) is responsible for up to one million under-five child deaths annually (World Health Organization, World Food Programme, United Nations System Standing Committee on Nutrition, The United Nations Children's Fund, 2007). SAM is still a public health concern in South Africa as the number of SAM cases increased from 21 598 in 2012/2013 to 23 743 in 2013/2014 (Massyn, Day, Peer, Padarath, Barron and English, 2014).

In 2014, chronic malnutrition resulting in stunting, affected an estimated 159 million children younger than five years globally (UNICEF, WHO and World Bank, 2015). The prevalence of stunting among preschool age children in Southern Africa was 32.9% in 2010 (De Onis, Blossner and Borghi, 2011). According to the South African National Health and Nutrition Examination Survey (SANHANES-1, 2012), stunting was highly prevalent among children younger than three years in South Africa with 26.9% of males and 25.9% of females in this age group being stunted (Shisana, Labadarios, Rehle, Simbayi, Zuma, Dhansay, Reddy, Parker, Hoosain, Naidoo, Hongoro, Mchiza, Steyn, Dwane, Makoae, Maluleke, Ramlagan, Zungu, Evans, Jacobs and Faber, 2013). This increase in the stunting prevalence in younger children compared to a lower prevalence in older children shows that stunting may become an increasing public health concern in future.

The nutritional status of children can be indicative of their long term health outcomes. Malnutrition is regarded as detrimental to individual as well as national economic output (Haddinott, Alderman, Behrman, Haddad and Horton, 2013). Childhood malnutrition contributes directly to the cost of health interventions as well as indirectly through caregiver opportunity losses while caring for a sick child (Hoddinott, Alderman, Behrman and Horton, 2013). A poor nutritional status in the early stages of the life cycle is known to contribute to the adult chronic disease burden (Barker, 2004). Malnutrition has been associated with poorer school performance and learning capacity (Fink & Rockers, 2014). It is also related to decreased work capacity, productivity and unachieved potential in the long term (Stewart, Iannotti, Dewey, Michaelson and Onyango, 2013).

Insufficient access to food is one of the underlying causes of malnutrition according to the UNICEF conceptual framework (UNICEF, 1997). According to Shisana *et al.* (2013), authors of the SANHANES-1 study, only 46.6% of South Africans are food secure. Food insecurity was observed in 26.0% of the sample and the remaining 28.3% were at risk of hunger (Shisana *et al.,* 2013). It was found that the prevalence of hunger was the highest in informal urban settings with an estimated 32.4% of people experiencing food insecurity (Shisana *et al.,* 2013). The black African and coloured populations had the highest rates of hunger and risk of food insecurity (Shisana *et al.,* 2013). Household food insecurity therefore puts these populations at a higher risk of developing malnutrition. Food insecurity has been shown to have a significant association with wasting in children (Motbainor, Worku and Kumie, 2015). Apart from food insecurity, childhood under-weight has also been associated with the total number of meals eaten per day (Motbainor, Worku and Kumie, 2015).

Malnutrition was considered as a major factor impeding South Africa's achievement of the Millennium Development Goals (MDGs) (Department of Health, 2013a). Schoeman, Faber, Adams, Smuts, Ford-Ngomane, Laubscher, Dhansay (2010) linked inadequate nutritional intake with an increased prevalence of respiratory tract infections, diarrhoea, fever and poor appetite in children. Intestinal infectious diseases, influenza/pneumonia and malnutrition were also listed as the three leading causes of death among South African children aged between one and four years old in 2011 (Statistics South Africa, 2014).

The South African Integrated Nutrition Programme (INP) aims at improving the nutritional status of children through targeted nutrition interventions (INP 2005). Growth monitoring and promotion is defined by the Department of Health (2013a) as "regular measurement, recording and interpretation of a child's growth in order to counsel, act and follow-up results with the purpose of promoting child health, human development and quality of life". To achieve this, early screening and identification of children who are at risk of becoming malnourished is a priority intervention (Kruger, 2014).

1.2 PROBLEM SETTING

The World Health Organisation (WHO) recommends using weight-for-height Z-scores (WHZ) or weight-for-length (WFL) Z-scores to identify children with SAM (WHO, 2013). Mid-upper arm circumference (MUAC) is also suggested by the WHO as a diagnostic tool for identifying acute malnutrition in children between six and 60 months of age (WHO, 2013).

Children with a WHZ of below -3 standard deviations (SD) of the WHO standard for children less than 60 months of age have a greatly elevated risk of death compared to children with a WHZ above -3 SD of this standard (WHO, 2006). The WHO therefore recommends the use of a WHZ of below -3 SD from the WHO standard to identify children with SAM (WHO 2013; WHO and UNICEF. 2009). A MUAC measurement of below 11.5cm is also recommended to identify SAM in children between six and 60 months of age (WHO 2013; WHO and UNICEF, 2009). A MUAC measurement of between 11.5cm and 12.5cm classifies a child between the ages of six and 60 months as moderately acutely malnourished (WHO 2013; WHO and UNICEF, 2009). According to the WHO and UNICEF (2009), WHZ and MUAC may be used interchangeably as a screening tool to identify malnourished infants and children, as they reveal a very similar prevalence of SAM in the field. The use of MUAC as a tool to identify children at risk for malnutrition offers many advantages over WHZ (Goossens, Bekele, Yun, Harczi, Ouannes and Shepherd, 2012).

Using MUAC alone to identify high-risk, malnourished children is seen by some researchers as acceptable as there seems to be no benefit in using WHZ in combination with MUAC or WHZ alone (Briend, Maire, Fontaine and Garenne, 2011). A MUAC tape is an inexpensive screening tool when compared with the scales, stadiometers and length boards required for determining WHZ. Cloete, Daniels, Jordaan, Derbyshire, Volmink and Schubl, (2013) concluded that health workers are capable of measuring and interpreting weight but are uncomfortable with weight and length measurements in combination, therefore WFH interpretations may not be performed routinely in the field. The WFH measurement may also be inaccurately interpreted. Community health workers and parents or guardians can easily be trained to use and interpret MUAC measurements as a screening tool (Goossens *et al.,* 2012; World Health Organization, World Food Programme, United Nations System Standing

Committee on Nutrition, The United Nations Children's Fund, 2007). A MUAC measurement is also non-invasive and thus generally well-accepted by infants and children. The practical simplicity of MUAC measurement aids in the reduction of errors occurring in anthropometric measurements of children (Goossens *et al.,* 2012). The rate of increase in arm circumference has also been reported parallel to the rate of weight gain in children (Goossens *et al.,* 2012). However, according to other researchers, MUAC identifies a higher number of children younger than two years old as being moderately acutely malnourished when compared with WHZ (Roberfroid, Huybregts, Lachat, Vrijiens, Kolsteren and Guesdon, 2015). This "accepted bias" is considered beneficial as the risk of death from malnutrition is highest among younger children. Therefore, children at the highest mortality risk are selectively included in interventions and treatments at an earlier age.

Although the WHO growth standard represents the optimum growth of children related to factors such as non-smoking mothers and exclusive breastfeeding during the first six months of life, South Africa has one of the lowest exclusive breastfeeding rates in the world (Siziba, Jerling, Hanekom and Wentzel-Viljoen 2015). It is therefore plausible that South African children are not growing in relation to the WHO growth standard charts, but are possibly shorter and fatter due to formula feeding practices and mixed feeding, thus more resembling the 1983 growth reference child described in Chapter 2.

According to Christian *et al.,* (2013), moderate stunting (HAZ<-2 SD) is prevalent among an estimated 20.8% of South African children younger than five years, while moderate wasting (WHZ<-2 SD) affected only 4.4%. Table 1.1 describes the mean WHZ and height for age Z-scores (HAZ) among South African children, highlighting the predominance of low HAZ compared with WHZ. The prevalence of moderate acute malnutrition (MAM) may differ by as much as 17.8% (95% CI 14.8%; 22.8%) in stunted children when identified by either MUAC or WHZ Z-scores (Roberfroid *et al.,* 2015). Steenkamp, Lategan and Raubenheimer (2016) questioned the sensitivity of the current MUAC cut-off values in areas such as South Africa, where there is a high prevalence of stunting.

Table 1.1: Wasting and stunting among South African children (Christian et al., 2013).

	Wasting	Stunting
Mean Z-score	0.3 (SD+-1.38)	-1.05 (SD+-1.85)
Prevalence	4.4%	20.8%

Considering South Africa's possible high level of subclinical malnutrition as caused by the nutrition transition, the sensitivity of MUAC equal to 12.5cm may be inappropriate for South Africa's wider, shorter children. This may be a cause of the phenomenon of the low prevalence of malnutrition in the community while simultaneously accounting for the high numbers of children seen in South African malnutrition wards.

Correcting MUAC for age or height does not improve the sensitivity for risk of death (Goossens *et al.,* 2012). Laillou *et al.* (2014) found that the WHO-recommended MUAC cut-off values identified a significantly different set of young children as being malnourished when compared with WHZ. Ali, Zachariah, Shams, Vernaeve, Alders, Salio, Manzi, Allaouna, Draguez, Delchevalerie and Harries (2013) recommend that a higher MUAC cut-off value might increase the number of children included in nutrition interventions, who are at high risk of nutritional deterioration.

Goossens *et al.* (2012) thus have suggested the development of community-specific adapted MUAC cut-off values for the treatment of malnutrition. The WHO (WHO, 2013) has highlighted the importance of testing strategies of refining MUAC cut-off criteria as a priority research area, "to improve active community screening and routine health-facility screening, and investigate barriers to service access and uptake, to enhance treatment coverage".

Details pertaining to child anthropometry are poorly represented in the Department of Health indicators. Only the under-weight-for-age incidence among children younger than two years and SAM incidence among children younger than five years old are reported in quarterly health statistics. Although Motherwell together with the Ibhayi townships in the Nelson Mandela Bay municipality are the source of 70% of reported SAM cases that were admitted to Dora Nginza Hospital in 2015, the Motherwell Community Health Centre reported the cumulative incidence of under-weight among children younger than two years as just four cases for April, May and June 2015. The Motherwell Mobile Clinic reported a total of only two under-weight-for-age children over the same three-month period. Motherwell NU11 clinic reported nine incidences of under-weight among children younger than two years (Department of Health, 2015). Therefore, health indicators not only neglect to report on linear growth (stunting) but figures available in the Motherwell area are questionably low. Furthermore, there is limited data on the nutritional status of children in the first 1000 days, also a time when infants are at the highest risk of death or inhibited growth (Kattula, Sakar, Sivarathinaswamy, Veluswamy, Venugopal, Naumova, Muliyil, Ward and Kang, 2014). The first 1000 days begins at conception, thus prenatal care, early infant feeding and the introduction of complementary foods are essential for health during this life stage. The first 1000 days ends at two years. Women and infants are seen regularly at clinics for antenatal and immunisation services. However, children younger than two years do not often go to clinics after their last immunisation at 18 months, and are also too young to go to crèches, therefore this age group has a high risk of being excluded from nutritional services. There is thus a need for more accurate and comprehensive data on child anthropometric status in poor areas like Motherwell in the Nelson Mandela Bay Health District (NMBHD) and to assess the efficacy of a simplified tool such as using MUAC to screen for malnutrition.

1.3 RESEARCH QUESTIONS

The following research questions were asked by the researcher:

1. What is the prevalence of stunting, wasting and overweight in children under two years of age in Motherwell?
2. Does MUAC correlate with WHZ in this population?
3. In the case that a correlation exists, can absolute MUAC predict WHZ?
4. What is the association between birth weight or food security and wasting and stunting?

1.4 RESEARCH AIM AND OBJECTIVES

This study aimed to synthesise a profile of the nutritional status of children younger than two years old in Motherwell, NMMM to assess the value of MUAC as a predictor of malnutrition risk and develop malnutrition screening recommendations relevant to this population.

Objectives included to:

- Describe anthropometric measurements, demographic information, information and food security data;
- Clean data according to WHO 2006 cleaning criteria;
- Determine associations between demographic indicators, anthropometric weight for age (WAZ), height for age (HAZ), weight for height (WHZ) Z-scores and MUAC measurements as well as food security data and birth weight;
- Determine correlations between wasting according to WHZ and MUAC;
- Determine sensitivity and specificity of MUAC as a predictor of malnutrition risk
- Develop malnutrition screening recommendations relevant to this population

1.5 ROLE OF THE RESEARCHER

Mr SW McLaren (BSc Dietetics; PG Dip Dietetics) is the primary investigator of the study. The duties of the primary investigator included developing the research proposal and submitting the research proposal to the Research Ethics Committee (Human) at Nelson Mandela Metropolitan University (NMMU). The researcher was also responsible for training field workers in accurately taking and interpreting anthropometric measurements in the field. This involved the development of an anthropometric manual for instructing community workers and research fieldworkers on the correct standard techniques, as well as regular training. The researcher directly participated in collecting and capturing data from the community, interpretation of data and prepared this dissertation.

1.6 LAYOUT OF THE DISSERTATION

In Chapter 1, the reader is briefly introduced to the current nutrition situation in South Africa and the Eastern Cape. Challenges faced at a community and primary health care level regarding anthropometric screening of children and identification of malnutrition are outlined, providing context and guiding the reader towards the research need, appreciating the aim and objectives of the study.

In Chapter 2, the current literature relating to the research question is reviewed. The understanding of malnutrition, its causes and effects has changed dramatically and evidence has emerged of the complex nature of malnutrition during childhood, of appropriate treatment as well as its long term effects on individuals. Together with this changing understanding of malnutrition itself, the screening methods for malnutrition have constantly evolved. The literature review focuses on the nutritional status of infants and young children, specifically considering associations between stunting, wasting and mid-upper arm circumference (MUAC) in this sector of the population. The use of MUAC as a predictor for malnutrition is investigated by reviewing similar studies conducted in similar settings.

In Chapter 3, the researcher provides the details of the methodology used in conducting the study. The methods chapter describes the study design that was employed. Aspects of the methodology including the instruments used, study population and sampling are described. This chapter also covers the validity and reliability of the study and relevant ethical considerations.

In Chapter 4, the results of the study are presented. This chapter describes the demographic information of the study sample. This chapter describes the anthropometric findings in terms of nutritional indicators including weight for age (WAZ), length for age (LFA), weight for height (WHZ) and MUAC measurements. Correlations between these indicators are explored in the context of the demographic data obtained. Anthropometric data obtained from the sample is used to model appropriate MUAC cut-off values specific to the population of Motherwell. The sensitivity and specificity of these recommended MUAC values is tested and presented. This chapter presents the association between anthropometric status and birth weight, household food security, age and gender as factors that influence the nutritional status of children and contribute to malnutrition.

In Chapter 5, the results of the study are discussed in relation to the available literature. The prevalence of malnutrition is assessed to determine whether under-weight, stunting and wasting prevalence is similar to the national trends. The relationship between MUAC and WHZ, and MAZ and WHZ demonstrated in chapter 4 is considered as a screening tool for malnutrition specific to the Motherwell population. The effects of low birth weight and HHFS on nutritional status of children younger than two years in Motherwell, NMB are discussed in the context of the South African trends. Finally, recommendations to develop guidelines for screening of children younger than

24 months in the Eastern Cape were formulated. This chapter also covers the limitations of the study.

CHAPTER 2: THE CHANGING FACE OF MALNUTRITION AND THE EVOLUTION OF NUTRITION SCREENING METHODS

2.1 INTRODUCTION

This chapter discusses the severity of childhood malnutrition in South Africa. The aim of this chapter is to familiarise the reader with the indicators commonly used to identify malnutrition. The effects of inadequate nutrition include linear growth retardation (known as stunting), poor weight gain resulting in under-weight and the loss of lean and adipose tissue (also referred to as wasting). While each of these conditions results from some degree of under-nutrition, the subtle differences in their aetiologies are explored. The underlying causes and effects of these nutritional conditions are discussed in this chapter. The nutrition transition from traditional diets to the more calorie-dense Western diets is affecting developing countries. This is discussed within the South African context. The nutrition transition has been identified as a possible cause for the double burden of disease the co-existence of over and under-nutrition. Overweight and obesity are becoming a prominent health issue in the developing world and children are not excluded from the risk of its development.

This chapter also draws on the literature describing the associations between stunting, under-weight, wasting and overweight. The WHO endorses MUAC as a criterion for identifying malnourished children. Absolute cut-off values have been suggested and are used in clinical practice for identifying children with SAM and moderate acute malnutrition (MAM). However, as the focus of primary health care is on the prevention of disease, some researchers have suggested alternative MUAC cut-off values for early detection of malnutrition. Published literature that describes MUAC as a predictor of malnutrition among children is examined.

Malnutrition refers to a spectrum of clinical conditions which includes kwashiorkor, marasmus, wasting, stunting and micronutrient deficiencies (Schoons *et al.,* 2013). Although it has been speculated that the symptoms of kwashiorkor were described in medicine as early as Hippocrates (Adams, 1939), malnutrition only became a focus of medical research during the early 20th century (Trowell and Davies, 1952). It had been noted that kwashiorkor was most prevalent among infants during the weaning phase, and could be linked to the poor quality of complementary foods (Trowell and Davies, 1952).

Wasting and stunting are conditions that are mostly caused by insufficient nutritional intake (Rossouw, Grant & Viljoen, 2012). According to Manary and Sandige (2008), malnutrition is the result of one or more macronutrients being unavailable in quantities necessary to maintain optimal body function. This is often associated with micronutrient deficiencies as well (Schoons *et al.,* 2013). However, for a large part of the 20^{th} century, it was believed that kwashiorkor was the result of protein deficiency (Trowell and Davies, 1952). It is now understood that kwashiorkor, known today as acute malnutrition, has a complex aetiology and is not usually due to simple protein or energy deficiency, and that treatment solely based on protein and energy intake results in higher mortality rates (Golden, 2010).

In spite of the progress into understanding its causes and pathogenesis, severe acute malnutrition remains a major health concern in developing regions today.

2.2 IMPACT OF MALNUTRITION ON CHILDREN

Apart from a high mortality risk (Mwangome, Fegan, Fulford, Prentice & Berkley, 2012), under-nutrition in childhood is associated with poorer cognitive development (Fink and Rockers, 2014), while optimal growth during infancy has a positive impact on cognitive development and education. Weight gain during the first two years of life has been significantly associated with the number of years of education a child received, as well as the risk of failing a school year (Martorell *et al.,* 2009). Catch-up growth in low birth weight infants was also associated with an increase in the number of years of education that children received (Martorell *et al.,* 2009), illustrating the importance of optimal growth in young children.

On the other hand, childhood malnutrition is also associated with an increased risk of developing overweight and obesity in adulthood (Pedro, Kahn, Pettifor, Tollman and Norris, 2014). Malnutrition during childhood often results in a shorter stature in adulthood (Haddinott, Alderman, Behrman, Haddad and Horton, 2013). This will raise the body mass index (BMI) as the weight is relatively high to height. A high BMI is considered a risk factor for chronic diseases. Stunting and wasting have also been linked with a higher chronic disease risk in adulthood (Prendergast and Humphrey, 2014). The nutritional status of children is therefore an extremely important determinant of their long term health and is the result of many social, economic and cultural factors (Schoeman, Faber, Adams, Smuts, Ford-Ngomane, Laubscher and Dhansay, 2010).

2.3 THE CAUSES OF MALNUTRITION IN CHILDREN

The UNICEF conceptual framework, as illustrated in Figure 2.1, outlines the causes of malnutrition among children. The causes of malnutrition are grouped into orders, from basic and underlying causes to the manifestations/outcomes of malnutrition. Not all of these factors will be discussed in the following section. Disease and insufficient access to food can manifest as acute malnutrition, but can also be responsible for poor growth in childhood.

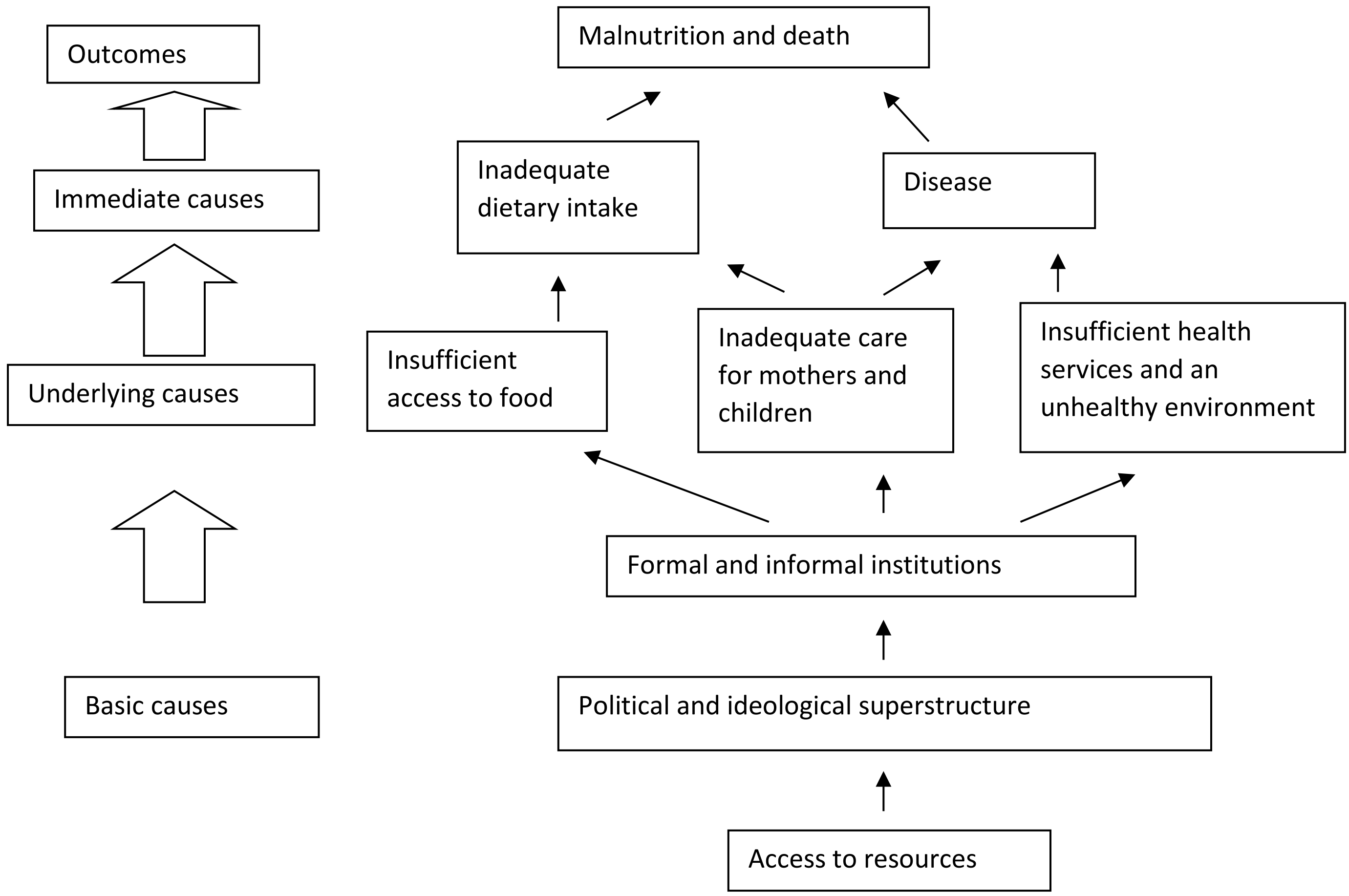

Figure 2.1: UNICEF Conceptual Framework on the Causes of Malnutrition (UNICEF 1997)

2.3.1 Underlying causes of malnutrition

Insufficient access to food leads to inadequate dietary intake. A compromised nutritional status makes individuals more prone to disease, a factor that further exacerbates malnutrition.

2.3.1.1 Insufficient access to food

According to the WHO 2013 Country Report on the MDGs from South Africa (WHO, 2013), the percentage of people who reported experiencing hunger was reduced from 29.9% in 2002 to 12.9% in 2011. However, estimates between surveys vary, and food insecurity and hunger still affect large numbers of South Africans. According to the results of the General Household Survey of 2013, 11.4% of the South African population was classified as suffering from hunger (Statistics South Africa, 2013). While 79.6% of South Africans had adequate access to food, 17.6% had inadequate food access and 6.1% had severely inadequate access (Statistics South Africa, 2013). In the Eastern Cape, only 70.6% of the population had adequate food access, 22.4% had inadequate access to food and 7.0% suffered severely inadequate access to food (Statistics South Africa, 2013) indicating a higher level of vulnerability. Earlier results from the National Food Consumption Survey (NFCS), indicated that 13% of South African children met less than half of their daily energy requirements and a further 26% met less than two thirds of their daily energy requirements (Labadarios *et al.,* 2005).

Differences in the estimates of the hunger and food insecurity prevalence may be due to differences in the methodology used for assessing hunger and food security among studies (Hendricks, 2014). According to the Department of Agriculture, Forestry and Fisheries data, South Africa is “food self-sufficient or nearly self-sufficient in almost all the major food products, with the ability to import shortages when necessary” (Du Toit, Ramonyai, Lubbe and Ntushelo, 2011: 4). Although South Africa is considered a food secure country on the basis of aggregate food availability, it is clear that hunger and household food insecurity continue to affect South Africans (Faber, Witten and Drimie, 2011).

The Gini co-efficient or Index is an estimate of the level of inequality in a given country, where a score of 0 predicts perfect equality, and a score of 100 is indicative of perfect inequality. South Africa has a Gini co-efficient of 67, making it one of the most unequal societies in the world (World Bank, 2015). Insufficient access to food at the community and household level results in inadequate dietary intake, aggravating one of the immediate causes of malnutrition.

2.3.2 Immediate causes of malnutrition

Inadequate access to food, particularly a diverse range of foods in the South African context, is the reason for the immediate cause of malnutrition, an inadequate dietary intake. This refers not just to the quantity of food available, but the quality of the food. Inadequate care for mothers and children stemming from underlying cultural and economic problems are also causes for an inadequate nutritional intake (Bain, Awah, Geraldine, Kindong, Siga, Bernard and Tanjeko, 2013).

2.3.2.1 The effect of hidden hunger on child growth

Although an individual may be meeting his daily energy requirements, the diet may be deficient in micronutrients. This form of under-nutrition does not necessarily result in a feeling of hunger perceived by the individual, and is known as “hidden hunger” (Kennedy, Nantel and Shetty, 2003). Hidden hunger may be indirectly responsible for poor growth and immune function which may contribute to stunting, under-weight and the resulting burden of under-five mortality. In sub-Saharan Africa it typically includes vitamin A deficiency and iron deficiency.

Vitamin A deficiency (VAD) is major health problem in developing regions of the world (WHO, 2009). Vitamin A deficiency is defined as a serum retinol concentration of less than 7*u*mol per litre as per WHO guidelines (WHO, 2011) and VAD is related to growth retardation in young children (Castejon, Ortega, Amaya, Gomez, Leal and Castejon, 2013).

As mentioned earlier, the NFCS conducted in South Africa in 1999 showed that South African children consumed less than two thirds of their Recommended Dietary Allowances (RDA) for energy, calcium, iron, zinc, selenium, vitamin A, vitamin D, vitamin C, Vitamin E, riboflavin, and folic acid (Labadarios *et al.,* 2005). The NFCS (2005) also revealed that 63.6% of the under-five population was vitamin A deficient while the SANHANES-1 (2013) reported a prevalence of 43.6%.

The reduction in vitamin A deficiency is possibly due to interventions including vitamin A supplementation, which began in South Africa in 2002 and food fortification, initiated in 2003. However, the Human Sciences Research Council warns that the current prevalence of 43.6% is still a major health problem.

Vitamin A is administered to children younger than five years at 6 month intervals. These supplements are in the form of oil-based drops containing 100 000IU to 200 00IU of vitamin A. The WHO recommends a minimum coverage of 80% of the under-five population for vitamin A supplementation to affect child mortality (Sommer, Djunaedi, Loeden, Tarwotjo, West, Tilden, Mele and the Aceh Study Group, 1986). Mayo-Wilson *et al*., (2011) reported that provision of high-dose vitamin A capsules resulted in a 24% decrease in all-cause child mortality.

The prevalence of vitamin A deficiency has been slow to respond to the rapid uptake of vitamin A supplementation programmes (Mason *et al.,* 2015) therefore VAD has not reduced proportionately to the increase in availability of Vitamin A supplementation. The criticism for the vitamin A supplementation programme is that the recommendations are 20 years old and have only been tested once (Mason et al., 2015). Mason *et al*. (2015) report that biannual vitamin A doses do not appear to reduce vitamin A deficiency itself.

Apart from VAD, a report by the WHO/CDC (2008) indicated that globally an estimated 600 million pre-school and school-aged children were anaemic. The South African national prevalence of anaemia was approximately 20% of children under five years in 1994 (SAVACG 1994). In 2013, 10.7% of children under the age of five years were anaemic (Shisana *et al*., 2013). The majority of these children were mildly anaemic (8.6%) and as there were no severely anaemic children, the remaining 2.1% were moderately anaemic. The prevalence of anaemia has decreased by 63% since 2005. Both VAD and iron deficiency may be linked to helminth infestation.

Iron supplements are not provided routinely to children in the same manner as vitamin A in the South African primary healthcare setting. There are concerns that iron supplementation could increase the number of morbidities from infections among children. In a randomised controlled trial, Sazawal, Black, Ramsan, Chwaya, Stoltzfus and Dutta (2006) found that supplementation with 12.5mg iron was related to a higher number of infections in children. A recent randomised, placebo-controlled trail tested the effect of low dose iron supplements (2.5mg) in the form of a home-based fortification powder (Barth-Jaeggi, Moretti, Kvalsvig, Holding, Njenga, Mwangi, Chhagan, Lacroix and Zimmermann, 2015). Iron supplementation had a significant positive effect on child weight (P=0.0038); however, iron-supplemented participants also reported a higher incidence of coughing (P=0.003) and dyspnoea (P=0.0002) than those receiving the placebo (Barth-Jaeggi *et al*., 2015). It was also found that supplementation was not effective in improving iron status. It is possible that doses of iron were too low and that a high prevalence of helminth infestations and infections rendered the supplemented iron ineffective (Barth-Jaeggi *et al*, 2015).

In a systematic review of randomised controlled trials, Sachdev, Gera and Nestel (2006) found that iron supplementation had no significant effect on the growth of children. The iron supplementation interventions reviewed included oral and parenteral iron supplements as well as iron-fortified infant formula and infant cereals. None of these interventions had any significant effect on the WFA, WFH, HFA or MUAC of infants and young children (Sachdev, Gera and Nestel, 2006). Although iron deficiency thus appears to affect growth, it is uncertain whether prophylactic use of iron supplements may prevent malnutrition.

2.3.2.2 Infectious diseases affecting child growth

Disease is one of the immediate causes of malnutrition according to the UNICEF conceptual framework. Sub-Saharan Africa is a region which has been widely affected by HIV, tuberculosis (TB) and malaria (WHO, 2015). The region is also affected by widespread poverty and a lack of infrastructure. Poor access to water and sanitation services as an underlying cause of malnutrition may cause diarrhoea, which increases the risk of developing acute malnutrition. Access to clean running water is better in urban areas of South Africa (Statistics South Africa, 2013). However, infectious diseases are still common in urban areas, especially in NMB (Mueller *et al.,* 2016).

HIV and AIDS

AIDS-related deaths totalled 1.7 million worldwide in 2011 (UNAIDS, 2012). According to UNAIDS (2012) there are 6 100 000 people living with HIV in South Africa. Of these, 410 000 were children under the age of 14 years. Despite the effective roll out of antiretroviral therapy (ART), 8255 people died due to AIDS in South Africa in 2011 (Statistics South Africa, 2014).

It is known that HIV progresses to symptomatic AIDS when the host's immune system is depleted by interactions with the HI virus (Lackner, Mohan and Veazy, 2009). HIV primarily targets T-cell lymphocytes in the host's mucosal organ systems. This makes people living with HIV and AIDS extremely susceptible to opportunistic infections such as tuberculosis, pneumonia and gastroenteritis (Rolfes, Pinna and Whitney, 2009). According to Kimani-Murage (2013), HIV has a significant effect on nutritional outcomes in children. There was a strong association between HIV and HAZ as well as WAZ in multiple regression models (Kimani-Murage, 2013). The authors reported that the number of HIV positive children in the study receiving ART was negligible. According to this study, mean values for HAZ, WAZ and WHZ were significantly lower ($p<0.05$) in HIV-infected children than non-infected children (Kimani-Murage, 2013).

Although HIV has a negative effect on child growth, access to antiretroviral medication improves the growth of HIV-infected children. A study on malnourished (WAZ, WHZ or HAZ <-2) HIV-positive children showed that significant catch up growth occurred in the 24 months following initiation onto ART (Jesson, Koumakpai, Diagne, Amorissani-Folquet, Koueta, Aka, Lawson-Eli, Dicko, Kouakou, Pety, Renner, Tanoh, Coffie, Desmonde and Leroy, 2015). Nevaripine prophylaxis has been shown to significantly reduce the wasting prevalence among HIV-exposed as well as HIV-positive infants within the first year of life (Ram, Gupte, Nayak, Kinikar, Khandave, Shankar, Sastry, Bollinger and Gupta, 2012). Antiretroviral therapy appears to have a positive effect on growth outcomes in infants and is related to the timing of infection and initiation onto ART (Ram *et al.,* 2012).

Shisana *et al.* (2014) reported in the South African National HIV Prevalence, Incidence and Behaviour Survey, that just 2.4% (95% CI 2.0-3.0) of South African children under the age of fourteen years are HIV positive. The Eastern Cape had a lower rate than the national average, with a prevalence of 1.3% (95% CI 0.7-2.3) HIV-positive children in this age group. Kimanyi-Murage (2013) reported an HIV prevalence of 4.4% (n=640) among South African children between one and four years old, indicating that new infections still occur despite an effective roll-out of the Prevention of Mother to Child Transmission (PMTCT) programme.

The HIV epidemic made an impact on child feeding practices in South Africa. Antiretroviral medication only became available in South Africa in 2004. Prior to the availability of ART, researchers questioned the effect of exclusive breastfeeding (EBF), formula feeding and mixed feeding practices on HIV transmission. Doherty, Chopra, Nkonki, Jackson and Greiner (2006) documented uncertainty about the safety of breastfeeding among HIV positive women. Cultural norms that are not conducive to breastfeeding, including the introduction of fluids and foods other than breastmilk as early as three months, were fed by the stigma and uncertainty attached to HIV (Doherty *et al.,* 2006). Mixed feeding, early introduction of complementary foods and choosing breastmilk substitutes have a negative impact on child growth and HIV infection risk.

Coutsoudis, Pillay, Spooner, Kuhn and Coovadia (1999) found that the rate of Mother to Child Transmission (MTCT) for exclusively breast-fed and exclusively formula-fed infants was comparable, and both were favourable compared with mixed feeding. Findings like this aided in forming infant feeding recommendations for HIV-positive women, which included exclusive breastfeeding.

Community-based support for HIV-positive pregnant women increased the likelihood of initiating ART during pregnancy in Nelson Mandela Bay (Fatti, Shaikh, Eley and Grimwood, 2016). Improved community based support for ART and increased coverage of child feeding information could aid in reducing vertical transmission of HIV and improve the growth of infants and young children.

Tuberculosis (TB)

The WHO Global TB Report of 2015 estimated the prevalence of TB in South Africa as 380 000 cases in 2014. The majority of South African TB cases are among adults between the ages of 25 to 64 years (Statistics South Africa, 2013). However, young children between 12 and 24 months old are also at a high risk of TB infection (Moyo, Verver, Mahomed, Hawkridge, Kibel, Hatherill, *et al.,* 2010). The TB prevalence in the community, housing structures, alcohol intake, population structure, the age of the child and level of interaction with the community are all factors that influence children's exposure to TB (Seddon and Shingadia, 2014). Tuberculosis contributed to 4.5% of the total mortalities among children between one and 14 years in South Africa (Statistics South Africa, 2013). Restricted resources in sub-Saharan Africa have created problems in the estimation of the childhood TB burden in the region (Seddon and Shingadia, 2014). Less than half of the children diagnosed with TB in a Western

Cape study had been identified as having TB prior to the study (Berman, Kibel, Fourie and Strebel, 1992), illustrating the difficulties in obtaining an accurate estimate of prevalence.

A TB infection directly contributes to the incidence of severe acute malnutrition (Collins, Dent, Binns, Bahwere, Sadler and Hallam, 2006). Fatigue, weakness, shortness of breath, chest pain and fever are common symptoms of TB. These symptoms make it difficult for adults infected with TB to continue working, resulting in loss of financial opportunity. Physical weakness creates problems for labour-intensive activities, including subsistence agriculture. These indirect effects of TB on livelihoods and food security also contribute to childhood malnutrition (Collins *et al.,* 2006).

2.3.3 Low birth weight (LBW) as a risk factor for malnutrition

Child under-nutrition may have its origins in the foetal stage of the life cycle (Christian *et al.,* 2013). A meta-analysis of 19 longitudinal birth cohorts from low- and middle-income countries revealed that small for gestational age children (birth weight less than 10^{th} percentile for gestational age) were 2.4 times more likely to be stunted, while preterm (less than 37 week gestation) children had 1.9 increased odds of stunting (Christian *et al.,* 2013). Children born who were both small for gestational age and preterm had a 4.5 times increased risk of stunting when compared with normal birth weight and term children (Christian *et al.,* 2013). Maternal health and nutrition is therefore an important factor in child under-nutrition.

According to the results of the Birth to 20 cohort study, the mean birth weight of South African children was 3.09kg (SD 0.51) with a gestational age of 38.1 weeks (SD=1.9) (Christian *et al.,* 2013). Low birth weight was prevalent among 9.9% and preterm birth occurred in 11.4% of South African children (Christian *et al.,* 2013). Low birth weight and small for gestational age status were significantly associated with stunting, wasting and under-weight in sub-Saharan countries, and other low- and middle-income countries (Christian *et al.,* 2013). A study by Prendergast, Rukobo, Chasekwa, Mutasa, Ntozini, Mbuya, Jones, Moulton, Stoltzfus and Humphrey (2014) asserts that stunting begins *in utero*, and is associated with chronic inflammation. As previously mentioned and presented in table 2.1, low birth weight is significantly associated with stunting (OR=2.77), wasting (OR=2.48) and under-weight (OR=3.48) in sub-Saharan countries, as well as other low- and middle-income countries (Christian et al., 2013).

The high risk of malnutrition in low birth weight infants is significant, considering the high rate of low birth weight in South Africa.

Table 2.1: Odds ratios for child under-nutrition and adverse birth factors in sub-Saharan and low- and middle-income countries (Christian et al., 2013).

Factors	**Sub-Saharan Africa Odds Ratio**	**Low- and middle-income countries odds ratio**
Stunting/LBW	2.77	2.92
Stunting/SGA	2.32	2.32
Stunting/Preterm	1.98	1.69
Wasting/LBW	2.48	2.68
Wasting/SGA	2.18	2.36
Wasting/Preterm	1.76	1.55
Under-weight/LBW	3.48	3.48
Under-weight/SGA	2.60	2.96
Under-weight/Preterm	2.05	1.66

As stated in chapter 1 under-nutrition, according to some researchers, may result in overweight later in life, however there is also evidence to the contrary. According to the findings of a meta-analysis conducted by Schellong, Schulz, Harder and Plageman (2012), low birth weight (<2500g) was associated with a decreased risk of future overweight in adulthood (OR=0.67; 95% CI 0.59, 0.76), while high birth weight (>4000g) was associated with an increased risk of adult overweight (OR=1.66; 95% CI 1.55-1.77). This highlights the complexity of the problem of child malnutrition in the first 1000 days. The underlying mechanisms for under-nutrition during childhood resulting in overweight in adulthood are discussed in more detail in section 2.6.4.1, “Potential causes of the double burden of disease”.

Foetal Alcohol Syndrome

A South African study estimated the prevalence of foetal alcohol syndrome (FAS) to be 59.3 to 91.0 per 1000 grade 1 learners (May, Blankenship, Marias, Gossage, Kalberg, Barnard, De Vries, Robinsn, Adnams, Buckley, Manning, Jones, Parry, Hoyme and Seedat, 2012). Partial FAS affects an estimated 45.3 to 69.6 per 1000 children which implies that 13.6% to 20.9% are affected by some form of the foetal alcohol syndrome spectrum (May *et al.,* 2012).

Research from the United States has linked FAS with abnormal eating behaviour in young children, which delays growth and increases the risk of nutritional deficiencies (Amos-Kroohs, Fink, Smith, Chin, Van Calcar, Wozniak and Smith, 2016). Children affected by FAS displayed delayed the acquisition of self-feeding behaviour ($p<0.001$) and delayed the introduction of solid foods ($P<0.002$) when compared with non-FAS controls (Amos-Kroohs *et al.,* 2016). Participants in this study with FAS were more likely to have been under-weight during some point in childhood than non-FAS ($p<0.001$) (Amos-Kroohs *et al.,* 2016).

Diarrhoea

Worldwide, diarrhoea is one of the leading causes of death among children younger than five years old (Black, Cousens, Johnson, Lawn and Rudan, 2010). Statistics South Africa (2011) reported that intestinal infectious diseases were the cause of death in 11.8% of the total mortalities for children younger than 14 years.

Rotavirus infection is a significant contributor to the incidence of diarrhoea in children younger than five years (Tate, Burton, Boschi-Pinto, Steele, Duque and Parashar, 2012). Mahmood, Khurshid, Mohammed, Iqbal and Khan (2005) reported that acute diarrhoeal episodes in infants are caused by mixed feeding practices and improper weaning practices. As diarrhoea and enteric infections cause malabsorption of nutrients and damage to the intestinal mucosa, Guerrant, DeBoer, Moore, Scharf and Lima (2013) have estimated that diarrhoea contributes to 43% of stunted growth seen among children.

Helminths

Helminths are common parasites of the human gastrointestinal tract. They are divided into three major groups, nematodes or roundworms, trematodes or flatworms and cestodes or tapeworms (Podolsky, Camiller, Fitz, Kalloo, Shanahan and Wang, 2015). Helminth infestations are a cause of malnutrition in children. Internal bleeding resulting in anaemia, as well as malabsorption of nutrients, diarrhoea and reduced appetite affect the nutritional intake and growth of children (Taylor-Robinson, Maayan, Soares-Weiser, Donegan and Graner, 2015). A recent randomised controlled trial showed that deworming with a single dose of 500mg mebendazole at 12 months of age had no effect on the growth of children at follow up (Joseph, Casapia, Montresor, Rahme, Ward and Marquis, 2015). However, current WHO guidelines still recommend periodic treatment with deworming medicines without previous individual diagnosis to all at-risk people living in endemic areas.

2.4 NUTRITION INDICATORS

The nutritional status of individuals is most often determined using anthropometric indices (UNICEF 2009). In adults, nutritional status is assessed using BMI while Weight for age, height for age and weight for height are indices endorsed by the WHO for determining nutritional status in children.

2.4.1 Growth reference standards for children

According to de Onis (2015), the interpretation of the infant growth trajectory is highly dependent on the growth charts used. In 2006, the WHO revised the international growth reference for infant and under-five child growth. The growth reference being replaced was called the US National Centre for Health Statistics (NCHS)/WHO International Growth Reference, referred to as the NCHS reference.

2.4.1.1 NCHS Growth reference

The NCHS growth reference was developed from longitudinal data collected by Ohio Fels Research Institute prior to 1975, and cross-sectional data from the US Health Examination Surveys from 1960 to 1975 (de Onis, Garza, Victora, Bhan and Norum, 2004). The international use of this growth reference was later in question as the Fels data did not include infants and young children from a range of socio-economic backgrounds and geographic locations and because the sample was predominantly formula-fed (de Onis, Garza, Victora, Bhan and Norum, 2004). Researchers and health workers were concerned with the applicability of the NCHS growth reference to populations outside of the United States and to individuals who were breast-fed.

Furthermore, samples for the NCHS reference were obtained from children at three month intervals and fitted to a curve. It was found that this method did not accurately represent the rapid and dynamic growth of infants during the first year of life (Cloete, *et al*, 2013).

2.4.1.2 The WHO Growth standard

These problems with the growth reference led to the development of the WHO 2006 growth standard (De Onis and the WHO Multicentre Growth Reference Study Group, 2006). The WHO 2006 growth standards included infants and young children from a diverse set of social, cultural and national backgrounds and described the growth trajectory of the breast-fed infant (de Onis, 2015).

2.4.1.3 The differences between the NCHS reference and WHO standards

Martorell and Young (2012) compared data from India and Guatemala, two developing countries with a high prevalence of child under-nutrition. Interpreting the same data using the two different guidelines (the older NCHS guidelines and the newer WHO guidelines) revealed completely different patterns of wasting (Martorell and Young, 2012).

The prevalence of wasting among infants younger than six months old in India as estimated by the WHO 2006 growth standard was three times higher than the estimation by NCHS growth reference definition (Martorell and Young, 2012). The prevalence of stunting was also higher using the WHO 2006 growth standard than the NCHS reference and stunting was most prevalent in infants younger than twelve months old (Martorell and Young, 2012). These findings display the differences in the growth trajectory between the formula-fed infant and the breast-fed infant, as the most significant differences were observed in the youngest groups

The apparent higher prevalence of wasting among breast-fed children using the WHO growth standard is explained by Duggan (2013). The WHO published a set of growth standards in 1983 for comparative nutritional assessment. The anthropometries of breast-fed and formula-fed infants during the first months of life differ significantly. All anthropometric indicators (WAZ, HAZ, WHZ) of formula-fed infants declined during the first two months of life, compared with breast-fed infants, who had higher WAZ and HAZ scores during the first two months (Alvarez-Uria, Midde, Pakam, Bachu and Naik, 2012). In 1983 the standard breast-fed infants were lighter than formula-fed infants after the first two months (Alvarez-Uria *et al*., 2012). The WHO 2006 growth standard infant is heavier and taller than the 1983 reference infant, then becomes lighter thereafter but still maintains a greater height (Duggan, 2013).

During the second year of life, the WHO 2006 child has a lower WHZ than the NCHS reference child, resulting in the child being identified as under-weight for height (SAM) at a greater WHZ than with the NCHS reference (Duggan, 2013). Martorell and Young (2012) found that the prevalence of SAM in India was higher when historic data was re-analysed using the WHO standard.

Therefore, differences in the growth standard and growth reference will result in alternative prevalences of wasting due to the differing growth trajectories, thus leading to different estimates of the prevalence of SAM depending on the standard used. Apparent differences in lean muscle mass between the formula-fed infant (NCHS reference) and breast-fed infant (WHO growth standard) groups may explain the higher prevalence of wasting in the Indian infants using the WHO 2006 growth reference to classify malnutrition.

The WHO standard is more likely to classify children as wasted than the NCHS reference. However, fewer children are identified as being underweight-for-age (WAZ<-2) using the WHO standard compared to the NCHS reference.

Therefore, although the WHO standard is more sensitive to SAM, identifying more cases than the NCHS, it has a higher specificity for under-weight children, resulting in fewer being identified as underweight than when using the NCHS reference. The WHO recommends the use of the WHO growth standard for assessing the nutritional status of children.

2.5 NUTRITION INDICATORS TO ASSESS NUTRITION STATUS IN CHILDREN

Anthropometry is the most universally applicable, non-invasive method of assessing growth in children (De Onis, 2015). The WHO Child Growth Standards represent normal growth under optimal environmental conditions and can be used to assess children everywhere, regardless of ethnicity, socio-economic status and type of feeding (De Onis, 2006).

Previously, the NCHS growth reference was used in the South African Road to Health Charts (RtHC) and was later replaced with the WHO growth standard charts in the new Road to Health Booklet (RtHB) that was introduced in 2011 (Cloete *et al.,* 2013). The RtHB includes the WAZ, HAZ and WHZ growth charts from birth to five years.

2.5.1 WAZ growth chart

Screening individual children for under-weight is done using the WAZ growth chart. Screening is ideally performed at the pre-clinical stage of disease progression (Wilson and Jungner, 1968). The WHO boys' WAZ growth chart included in the South African RtHB is presented in Figure 2.2. Infants and young children are weighed monthly at clinic visits in South Africa according to INP guidelines and their weight is then supposed to be plotted at their corresponding age on the WAZ growth chart. As WAZ progresses chronologically, the growth curve of the child can be used to retrospectively "tell a story" about the child's road to health. Trends in the growth curve such as a slowing growth trajectory (growth faltering) can also be used to screen for malnutrition before it reaches the clinical stage of acute malnutrition.

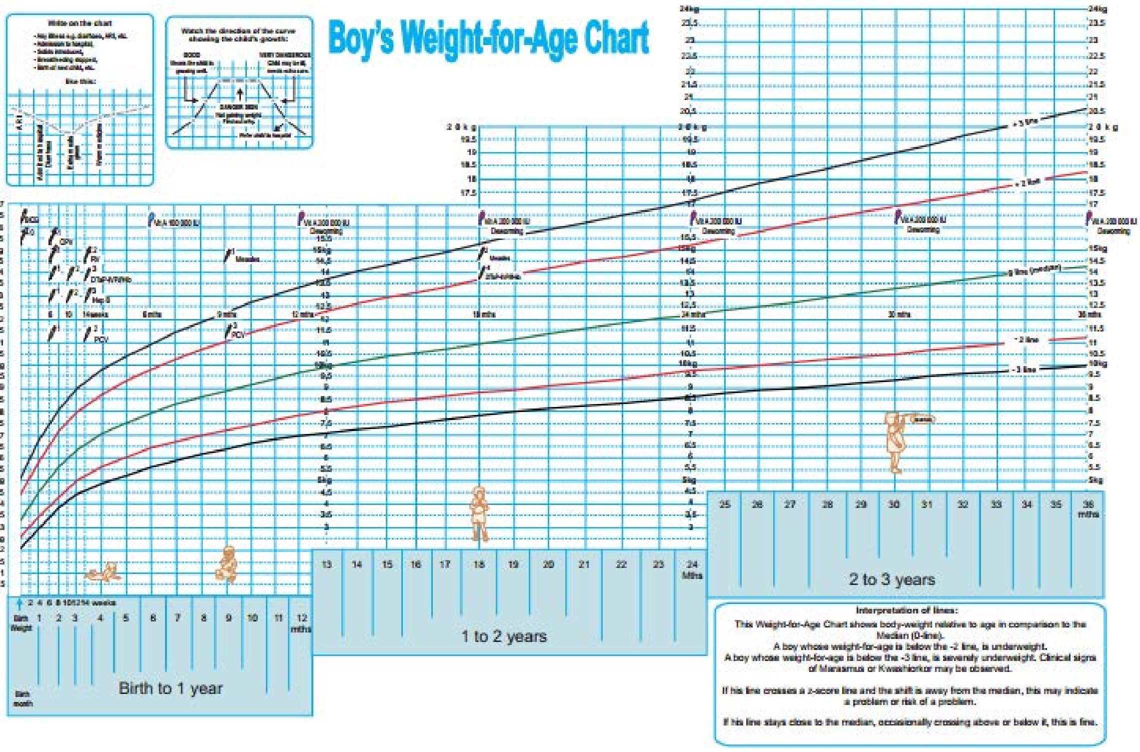

Figure 2.2: Boys weight for age Z score chart

The differences in growth trajectories between genders was not considered in the old RtHCs. However the difference is large. As shown in Table 2.2, girls gain weight more slowly than boys according to the WHO standards. The example was calculated using WHO Anthro software. The male and female examples were constructed using the same birth dates and dates of measurements, and the same weights at these events.

Table 2.2: Differences in growth trajectories (weight-for-age) of male and female infants using WHO Anthro

Age (months)	**Weight (kg)**	**WAZ male**	**WAZ female**
0	3.00	-0.73	-0.52
5	6.00	-2.01	-1.15
10	7.00	-2.45	-1.60

The male WAZ crosses the -2 Z score line at five months and remains below the -2 line at ten months of age, classifying the infant as moderately under-weight for age. The female WAZ does not cross the -2 line at five or ten months, remaining in the "normal" classification. Gender-specific interpretation of growth standards is thus of the utmost importance.

The classification of WAZ categories is presented in Table 2.3. WAZ is used to discern a child of normal weight for their age and gender from one who is under-weight. The severity of under-weight is graded according to positions on the growth chart.

Table 2.3: Interpretations of position on weight for age growth chart

Position on Growth Chart	**Interpretation**
WAZ > +3	Possibly overweight: confirm with WFL Z-score
WAZ > +2	
-1 > WAZ > +2	Normal weight (growing well)
-1 > WAZ > -2	Mildly under-weight
WAZ < -2	Moderately under-weight
WAZ < -3	Severely under-weight

Surveillance is the periodic collection, analysis and reporting of information in order to prevent disease (Halperin and Baker, 1992). Johnson, Vazir, Fernandez-Rao, Kankipati, Balakrishna and Griffiths (2012) recommend using the WHO growth standard for nutrition surveys aimed at targeting nutrition intervention programmes at infants who are at the highest risk for malnutrition. This is because, as previously explained, the WHO growth standard is less likely to classify infants as under-weight for age (WAZ<-2) than the NCHS reference, thus ensuring the most malnourished infants are targeted (Johnson *et al.,* 2012).

2.5.2 HAZ growth chart

The HAZ growth chart is included in the South African RtHB and is shown in Figure 2.3. This growth chart is used to identify stunted children. The interpretation of the positions on the HAZ growth chart is presented in Table 2.4.

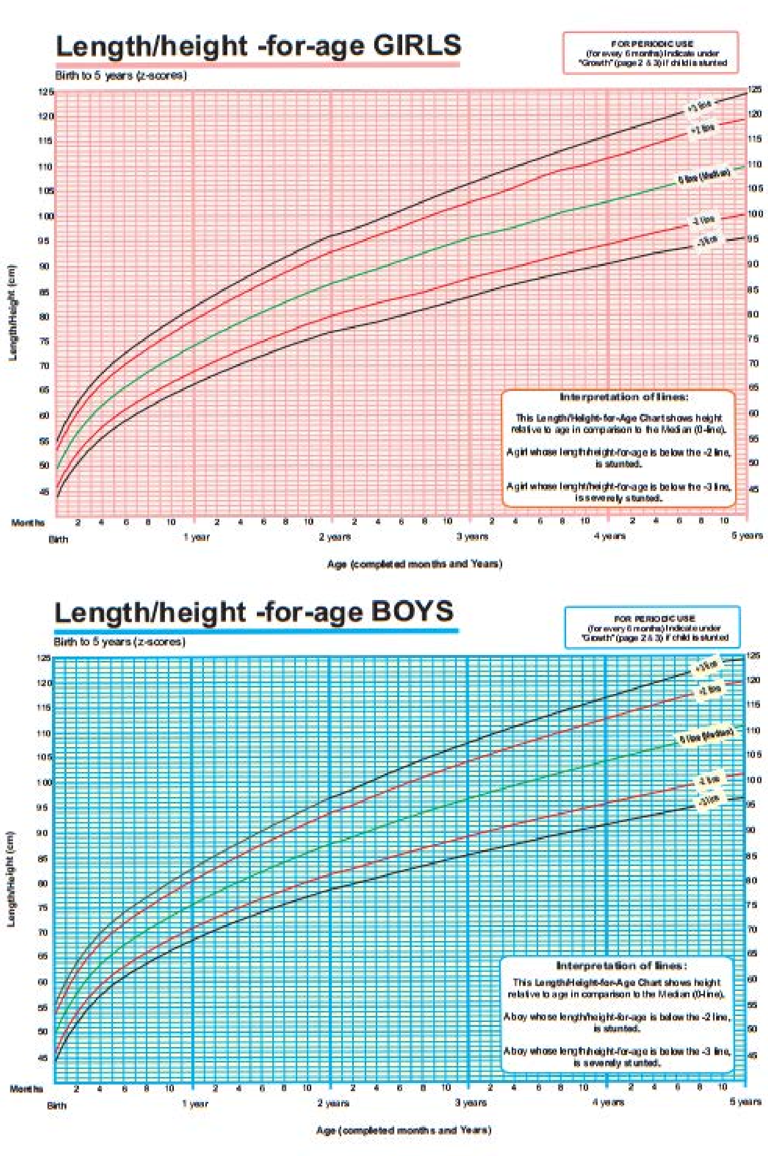

Figure 2.3: WHO length for age Z score chart

Table 2.4: Interpretation of position of plot on height for age growth chart

Position on Growth Chart	**Interpretation**
Above the +2 line	Normal height (growing well)
Between the +2 and -1 lines	
Between -1 and -2 lines	Mildly stunted
Below the -2 line	Moderately stunted
Below the -3 line	Severely stunted

Gender differences

Girls have a slower growth trajectory than boys in terms of weight, as well as in height in the first few months of life. As shown in Table 2.5 below, males and females of the same height at the same age have different HAZ scores. A five-month old male who is 60cm tall is classified as stunted (HAZ<-2) whereas a female of the same age and height is classified as normal (HAZ<0).

Table 2.5: Differences between males' and females' growth trajectories in the first year of life according to WHO standard

Age (months)	**Height (cm)**	**HAZ Male**	**HAZ Female**
0	50	0.06	0.46
5	60	-2.82	-1.84
10	65	-3.63	-2.64

It is recommended that height is measured and interpreted every six months. HAZ status at 12 months of age was predictive of anthropometric status at 36 months (Mamabolo, Alberts, Steyn, Delemarre-van de Waal and Levitt, 2005), meaning that regularly monitoring length allows for early correction of linear growth retardation.

2.5.3 WHZ growth chart

The WHZ growth chart is used to describe a child's weight relative to his or her height, independently of their age. This growth chart is presented in Figure 2.4. The WHZ growth chart is the gold standard for screening for acute malnutrition in children (WHO 2013). The height and weight values for the WHO 2006 growth chart follow a narrower range than the 1983 reference chart, thus SAM is identified when a child is at higher weight and height than using older growth references (Duggan, 2013).

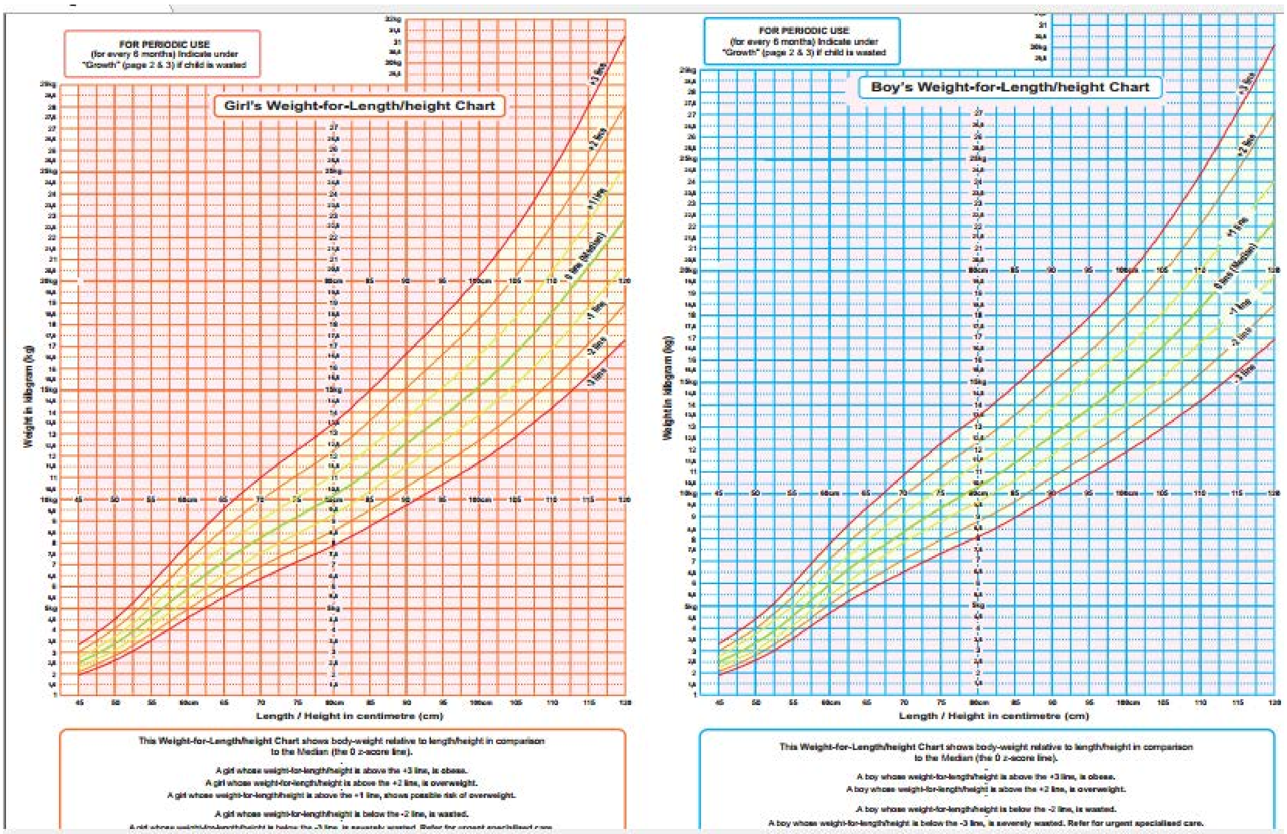

Figure 2.4: WHO weight for length Z score charts

The WHZ chart can be used as an index to assess weight loss over a short period of time. This is because the weight loss can occur rapidly as a result of insufficient food intake or infection, whereas length or height tends to be static or increase slowly. Thus WHZ is used to assess for acute malnutrition. The interpretations of the WHZ growth chart positions are given in Table 2.5.5.

Table 2.6: Interpretation of plot position on the weight for length growth chart

Position on Growth Chart	Interpretation
Above +2 line	Overweight
Between +2 and -1 line	Normal weight for height (growing well; or both stunted and under-weight at the same time)
Between -1 and -2 line	Mild Acute Malnutrition
Below -2 line	Moderate Acute Malnutrition
Below -3 line	Severe Acute Malnutrition

2.6 THE CHANGING FACE OF MALNUTRITION IN THE 21ST CENTURY

Malnutrition is becoming an increasingly complicated public health issue. Globally, malnutrition figures are shifting and the effects on nutritional status of children are being seen by researchers in South Africa. Concurrent problems of wasting, stunting and overweight and obesity among children are being driven by factors discussed under the UNICEF conceptual framework, including disease and the availability of food.

2.6.1 Stunting: an increasing concern

2.6.1.1 Global trends

According to Black, Victora, Walker, Bhutta Christian, De Onis, Ezzati, Grantham-McGregor, Katz, Martorell and Uauy (2013), the global prevalence of stunting is decreasing. In 1990, it was estimated that 40.3% of preschool age children were stunted in Africa, and the prevalence of stunting in this age group is predicted to be 37.1% (95% CI 33.6% to 40.6%) in 2020 for the continent.

However, despite this decrease an estimated 165 million children under the age of five were stunted in 2014 (UNICEF, WHO and World Bank, 2015). Furthermore, these improvements are not uniformly spread throughout the world's regions. Latin America and the Caribbean are predicted to more than halve the prevalence of stunting between 1990 and 2020. Yadav, Gupta and Shrestha (2014) observed severe stunting among 21.6% and moderate stunting among 20.7% of a sample of 615 children under three years old in Nepal. However, a higher prevalence of stunting was found among a sample of Ethiopian children younger than five years (n=3964), where 37.6% suffered from moderate stunting, and 14.2% were severely stunted. In this study, the prevalence of stunting and severe stunting was found to be similar between boys and girls (Mobainor, Worku and Kumie, 2015). Stunting was also prevalent in 25.3% (n=445) among primary school-aged children (seven to 14 years) in Ethiopia (Wolde, Berhan and Chala, 2015). Stunting thus remains a child health problem across the world although progress is being made in reducing its prevalence.

2.6.1.2 South African trends

In spite of the global improvements in the stunting prevalence, stunting continues to be a major problem in Southern Africa, affecting almost one third of preschool age children in the region (De Onis, Blossner and Borghi, 2010). It was estimated that stunting affected 35.4% (95% CI 37.7% to 42.8%) of the pre-school age population of Southern Africa in 1990 (De Onis, Blossner and Borghi, 2011).

The results of the SAVACG study (1994) revealed that a quarter of South African children under the age of five years were stunted in 1994. In the same year, Popkin, Richards and Montiero (1996) estimated the prevalence of stunting among South African children (n=2467) between one and three years old as 28.5% (Popkin, Richards and Montiero, 1996). Stunting was prevalent in 32.9% of pre-school age children in Southern Africa in 2010 (95% CI 27.7% to 38.9%). De Onis, Blossner and Borghi (2011) predicted that 31.7% (95% CI 33.6% to 40.6%) of children under the age of five years will be stunted in 2020. Despite efforts at reducing the prevalence of stunting in South Africa, there has not been a significant reduction in stunting in the past 25 years.

Schoeman *et al*. (2010) found that 13% of infants under eleven months old (n=332), 25% of young children between 12 and 23 months old (n=222) and 25% of children aged between 24 and 59 months (n=411) were stunted in samples drawn from three rural districts in the Eastern Cape and KwaZulu-Natal. A study conducted in the Limpopo province found that the prevalence of stunting among children younger than 36 months old was as high as 48% (Mamabolo, Alberts, Steyn, Delemarre-van de

Waal and Levitt, 2005). It is therefore evident that wide variances can be observed among the various provinces in South Africa.

Cross sectional studies allow for comparison of the stunting prevalence for varying age groups in South Africa. Studies show that stunting is highest among infants (Kimani-Murage, 2013) and tends to decrease as children grow older. Tathiah, Mubaiwa, Denny and Taylor (2013) estimated that stunting was prevalent among 9.2% of South African primary school-aged girls. Pedro *et al.* (2014) found a similar prevalence of stunting among children and adolescents. Stunting affected more boys than girls (Pedro *et al.* 2014). The prevalence of stunting appears to increase again during adolescence. This would suggest opportunities for catch-up growth however stunting is still considered a chronic condition (Richard, Black, Gilman, Guerrant, Kang, Lontana, Molbak, Rasmussen, Sack, Valentiner-Branth and Checkley, 2012).

2.6.1.3 Causes of stunting

Keino, Plasqui, Ettyang and van den Bourne (2014) linked the increased prevalence of stunting with socioeconomic, demographic and environmental factors among children aged less than five years in sub-Saharan Africa. These researchers found that there was a direct link between stunting and the mothers' education, occupation and household income. People residing in rural areas, and especially males, were more vulnerable to stunting.

Similar results were observed in India, where Chowdhury, Sinha, Adhikang, Mulchergee and Lahiri (2013) showed that the risk of stunting among children between six and 59 months old was significantly related to socio-economic factors. The risk of stunting in children was higher among those households with reduced buying power and access to resources because of unemployment (Chowdry *et al.,* 2013). Stunting was also significantly higher among males and in younger infants (Chowdry *et al.,* 2013).

Among the causes of stunting described by the Conceptual Framework on Stunting (WHO 2013) are poor micronutrient quality, low dietary diversity and intake of animal foods, the anti-nutrient content of the diet and low energy content of complementary foods. The underlying causes of stunting are presented in figure 2.5 below. In a study of internally-displaced people, Ali, Ayub and Hussain (2015) found that there was an association between late and early weaning and under-nutrition in children.

Complementary feeding was initiated before six months of age in 52% of their sample. A delayed introduction to complementary food was also associated with under-nutrition (stunting, wasting, under-weight for age) (Ali, Ayub and Hussain, 2015). Apart from that, a large family size was positively associated with wasting, stunting and under-weight for age (Ali, Ayub and Hussain, 2015). Dietary diversity and the number of meals eaten per day were linked with stunting in a study on Ethiopian children younger than five years old (Motbainor, Worku & Kumie, 2015).

Figure 2.5: Conceptual Framework of stunting (Stewart, Iannotti, Dewey, Michaelsen and Onyango 2013).

Stunting prevalence differed significantly between urban and rural groups of Peruvian children (Pomeroy, Stock, Stanojevic, Miranda, Cole and Wells, 2014). According to Pomeroy *et al*. (2014), rural children appear to be at a higher risk of stunting. Stunting was also significantly associated with the duration of exclusive breast-feeding and choosing to exclusively formula-feed in India (Chowdry *et al.,* 2013).

The risk of stunting in children was associated with having student/younger mothers (Mamabolo *et al.,* 2005). With a teenage fertility rate of 52 per 1000 adolescent girls for the years 2006-2009 (Makiwane, 2010), this could contribute to stunting in South Africa.

2.6.1.4 Prevention/treatment of stunting

Hoddinott *et al*. (2013) have suggested that investing in strategies which have been proven to reduce stunting among children will have extremely favourable economic outcomes in the long term. These strategies include universal salt iodization, multiple micronutrient supplementation, community-based intervention strategies for improving breast-feeding and complementary feeding strategies, community based management of SAM (Hoddinott *et al*., 2013). Applying the strategies intended to reduce stunting as suggested by Hoddinott *et al*. (2013) results in a benefit:cost ratio of between 3.5 (Democratic Republic of Congo) to 24.4 (Nigeria) in the sub-Saharan African context.

2.6.2 Wasting

2.6.2.1 Global trends

Acute malnutrition is caused by insufficient dietary intake or illness. Severe acute malnutrition (SAM) is a condition characterised by severe wasting, anorexia, micronutrient deficiency, electrolyte imbalance and oedema and dehydration (WHO, 2013).

An estimated 20 million children of pre-school age are affected by SAM globally (United Nations Interagency Group for Child Mortality Estimation, 2012). Kerac, Blencowe, Grijalva-Eternod, McGrath, Shoham, Cole and Seal (2011) estimated that there were approximately 3.8 million infants under the age of six months who were severely wasted and a further 4.7 million infants below six months who were moderately wasted in developing countries, using WHO standards to define wasting. It was also found that one in ten children in this age group was under-weight.

In 2011 at least 52 million children under the age of five years were wasted globally (Black, Victora, Walker, Bhutta Christian, De Onis, Ezzati, Grantham-McGregor, Katz, Martorell and Uauy, 2013). Both moderate and severe wasting were more prevalent among infants and children younger than three years than those older than three years in studies in Nepal and Ethiopia (Yadav, Gupta & Shrestha, 2014; Motbainor, Worku and Kumie, 2015). Moderate and severe wasting was more prevalent in males than in females in this sample (Motbainor, Worku and Kumie, 2015). Wasting was highest among children aged between six and eleven months (n=463) (Motbainor, Worku and Kumie, 2015). Similarly, in a study conducted in India by Qureshi, Qureshi, Syed and Kokku (2014), it was found that wasting was most prevalent among younger infants and children.

2.6.2.2 South African trends

The prevalence of wasting defined as WHZ<-2 SD among black children and adolescents living in Mpumalanga was low in a study conducted by Pedro *et al.* (2014). It was found that 1% of boys (n=292) and 0.3% of girls were wasted (n=296). Similarly, wasting was found among 1% of a sample (n=162) of infants and children younger than three years (Mamabolo *et al.,* 2005). Kruger, Pienaar and Coetzee (2013) found wasting present in 8.35% of male grade-1 learners (n=419) and 5.97% of female grade-1 learners (n=397). The difference between genders was not significant (Kruger, Pienaar and Coetzee, 2013). Thus the prevalence of wasting in South Africa is not as high as other developing nations.

2.6.2.3 Causes of wasting

Using data from cross-sectional surveys conducted in Somalia between 2007 and 2010, Kinyoki, Berkley, Moloney, Kendala and Noor (2015) found that wasting was significantly associated with fever and diarrhoea. In this study, wasting was also associated with household food insecurity. This result was reflected in the study conducted by Steenkamp *et al.* (2016), where food insecurity was associated with wasting. Rytter, Namusoke, Babirekere-Iriso, Kaestel, Girma, Christensen, Michaelsen and Friis (2015) found that low dietary diversity increased the risk of oedematous SAM, and that oedema was more likely to present in SAM cases where the child was not breast-fed.

2.6.2.4 Pathogenesis of wasting

Changes in metabolism, as described by Freemark (2015) in SAM in children between six and 59 months of age, may aid in explaining the mechanism of wasting. Malnourished children have raised serum levels of non-esterified fatty acids, ketones and even-chained acylglycerides, which indicate accelerated fat metabolism or lipolysis (Freemark, 2015; Bartz, Mody, Hornik, Bain, Muelhbauer, Kiyimba, Kiboneka, Stevens, Bartlett, St Perter, Newgard and Freemark, 2014). Low serum concentrations of albumin, free amino acids, propionyl (C3) carnitine and other by-products of branched chain amino acid metabolism would suggest that the muscle stores are protected. Raised growth hormone concentrations and lower insulin secretion stimulate hepatic glucose production and gluconeogenesis, increasing lipolysis and decreasing the rate of proteolysis. This would suggest that the adipose reserves are depleted quickly in favour of lean muscle tissue and vital organ tissue as an adaption to starvation. Infants and young children have little muscle tissue relative to their weight in comparison to adults. This may be a contributing factor as to why fat is used as the preferred source of energy in children suffering from starvation (Briend, Khara and Dolan, 2015). However, muscle tissue, which is largely located in the limbs, is also wasted during periods of stress.

2.6.2.5 Prevention/treatment of wasting

Prevention and treatment of SAM begins with routine growth monitoring (Figure 2.6). Screening algorithms recommend inspecting the child for oedema as a complication of SAM. The presence of bilateral pitting oedema is an independent criterion for the identification of SAM (WHO guidelines). In the absence of oedema, anthropometric measurements take place and WHZ is calculated. The MUAC measures the circumference of the arm including bone, muscle, adipose and dermal tissues and may therefore be used as an indirect method to assess the degree of wasting of fat and muscle stores in infants and young children (Briend, Khara and Dolan, 2015).

It has been suggested that preventive strategies for SAM have failed (Golden, 2010).

Treatment of SAM relies on applying the WHO Guidelines for the Inpatient management of SAM with products such as F-75, F-100 and RUTF, as well as appropriate management of complications (Golden, 2010).

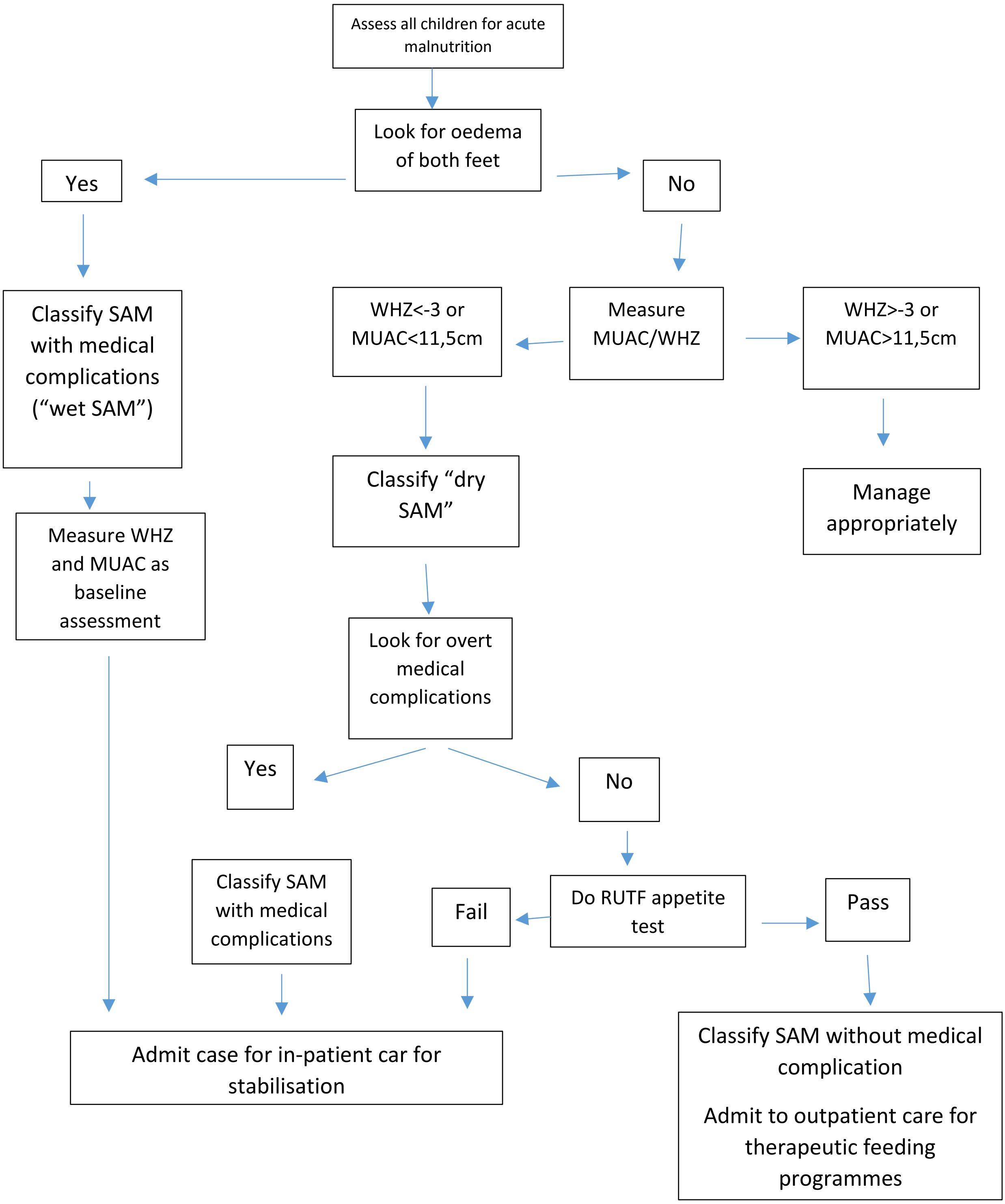

Figure 2.6: Algorithm for identifying SAM cases

The WHO's Ten Steps for Treatment of Severe Acute Malnutrition is still considered the "gold standard" for the management of SAM. The duration of treatment is divided into three phases. Initial treatment begins with resuscitation which takes place over the first one to two days. Initial treatment continues until day 7 of treatment and is also known as the stabilisation phase (WHO 2006). This phase of treatment is characterised by anorexia, and significant oedema in complicated cases. The rehabilitation phase takes place over the weeks following the initial treatment phase, as the child's appetite increases. After the child has been discharged from inpatient care, follow-up treatment is recommended until 26 weeks post-initiation. The time frame and timing of the ten steps is illustrated in Figure 2.7.

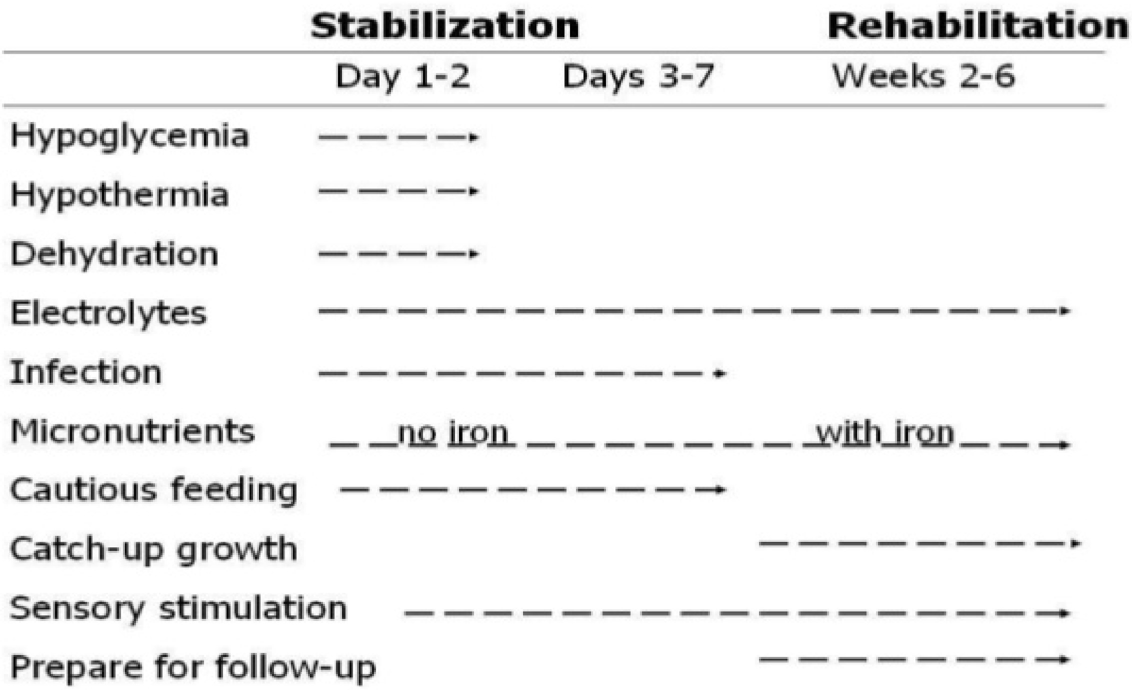

Figure 2.7: Timing of the WHO ten steps for treatment of severe acute malnutrition

Considering the difficulty in treating severe acute malnutrition, it is apparent that the focus should be on early detection and treatment of wasting.

2.6.3 Obesity

2.6.3.1 Global trends

The prevalence of overweight and obesity among children is increasing. The global prevalence of childhood overweight and obesity rose from 4.2% to 6.7% between 1990 and 2010 (De Onis, Blossner and Borghi, 2010). De Onis, Blossner and Borghi (2010) estimate the global prevalence to reach 60 million by 2020. Of the estimated 43 million overweight and obese children worldwide, 35 million were from developing countries (De Onis, Blossner and Borghi, 2010). In one study 8.5% of African children were estimated to be overweight or obese (De Onis, Blossner and Borghi, 2010). Overweight was prevalent among 7.4% and obesity among 2.5% of children between seven and 14 years old (n=445) in Ethiopia (Wolde, Berhan and Chala, 2015).

2.6.3.2 South African trends

Overweight and obesity appears to be prevalent among South African adolescents and affects more females than males according to a study conducted in Mpumalanga (Pedro et al., 2014). However, Mamabolo *et al*. (2005) have shown that overweight and obesity are also a common nutritional problem among children younger than three years of age. Schoeman *et al*. (2010) showed that a high prevalence of overweight and obesity was present among infants younger than one year old in rural districts of the Eastern Cape and KwaZulu-Natal.

In their study on rural black South African children, Craig, Reilly and Bland (2015) found that females had a far greater risk of being overweight than males. Overweight was defined as BMI-for-age greater than +1 SD, in alignment with WHO 2007 recommendations. This study differentiated overweight from “overfat”. Overweight refers to the BMI definition, whereas overfat refers to a high body fat percentage as measured by bioelectrical impedance. Overweight was observed among 73.9% of the female participants, compared with 26.1% of male participants (Craig, Reilly and Bland, 2015). The prevalence of overfat and overweight were similar among males and females (Craig, Reilly and Bland, 2015). It was also found that the risk of overweight increased with age in this study. Grade 1 learners had an adjusted odds ratio (AOR) of 0.65, grade 5 learners an AOR of 0.50 and grade 9 learners and AOR of 1.00, suggesting that the risk of overweight increases with age in childhood (Craig, Reilly and Bland, 2015). Tolriola *et al.* (2012) found that overweight and overfat peaked among twleve year old children and tapered in older children. Jacobs and de Ridder (2012) conducted a study in South Africa's North West province and found no significant difference in BMI or body fat percentage between groups of eleven, twelve and thirteen year olds at the $p<0.05$ level.

Overweight and obesity were prevalent among 9% and 3.8% of primary school-age South African girls (n=963) respectively (Tathiah *et al.,* 2014). The highest overweight rate was found among ten-year-old girls and obesity was most prevalent at twelve years of age (Tathiah *et al.,* 2014). According to Toriola, Moselakgama, Shaw and Boon (2012), the risk of overweight in rural black South African children between ten and sixteen years old is higher among females than males, however these researchers observed a higher prevalence of obesity among males than females.

Popkin, Richards and Montiero (1996) found that 7.3% of South African children between three and six years old were overweight in 1994. This was higher than in Brazil, but lower than China and Russia (Popkin, Richards and Montiero, 1996). Comparisons of nutritional status for South Africa and other countries can be found in Table 2.7.

2.6.3.3 Causes of obesity

Changes in eating behaviours and physical activity levels contribute to the increasing prevalence of obesity in dual-burden countries (Ramachandran, 2011). Ramachandran (2011) reported that there was an increase in per capita total energy, protein and fat intake but a reduction in micronutrient intake in India between 1975 and 1996. This phenomenon coincided with an 18% fall in rural areas and 22% in urban areas in per capita expenditure on food. It was suggested that this was caused by a fall in expenditure on cereals as well as the low cost of cereals, especially subsidised cereals, in low income groups (Ramachandran, 2011). Similarly, South African dietary patterns have changed over the past few decades. Goedecke, Jennings and Lambert (2005) reported that carbohydrate consumption among South African adults living in urban areas decreased by 10.9% between 1940 and 1990, while fat intake increased by 59.7%. In comparison, fat intake among South African adults in rural areas increased by only 8%, while carbohydrate intake decreased by 10% between 1970 and 1990 (Goedecke, Jennings and Lambert, 2005).

The contrast between urban and rural dietary composition puts urbanisation at the forefront of the causes of the nutrition transition taking place in the developing world. However, more recent studies have shown that the effects of the nutrition transition are becoming more prevalent in rural areas as well. Kimani-Murage (2013) showed that stunting and overweight co-exist in rural South African communities, particularly affecting girls. Pedro, Kahn, Tollman and Norris (2014) discovered high rates of glucose intolerance and pre-hypertension among rural South African adolescents. Igumbor, Sanders, Puoane, Tsolekile, Schwarz, Purdy, Swart, Durao and Hawkes (2012) suggested that rapid urbanisation and monopolies on food production and distribution are significant factors in the nutrition transition in South Africa. Processed and prepared foods are generally high in calories, fat and salt. These foods are rapidly becoming more affordable, accessible and acceptable to all populations in South Africa, including rural and informal settlements (Igumbor *et al.,* 2012). Unexpectedly high proportions of South Africans living in rural areas purchase their food from supermarkets, perhaps explaining the presence of the nutritional double burden in rural as well as urban communities (D'Haese and Huylenbroek, 2005). Changes in sales volumes of processed and convenience foods reveal that sales of these foods increased dramatically in South Africa between 2005 and 2010 (Igumbor *et al.,* 2012). Maize is a leading staple crop in sub-Saharan Africa (Pillay *et al.,* 2011) and according to the NFCS of 1999, maize was the most commonly consumed food item in South Africa followed by sugar, tea, whole milk and brown bread (Labadarios *et al.,* 2005).

Among children under five years living in rural South African areas, overweight was associated with an irregular source of household income (Lesiapeto, Smuts, Hanekom, Du Plessis and Faber, 2010).

2.6.3.4 Prevention/treatment of obesity in children

Interventions aimed at reducing overweight and obesity should be directed towards pre-adolescent and adolescent girls, as this population group displays high levels of overweight and obesity in rural South Africa (Craig, Reilly and Bland, 2015).

However, according to a systematic review on the effectiveness of interventions into childhood overweight, none of the interventions reviewed had any effect on preventing childhood overweight and obesity (Monasta, Batty, Macaluso, Ronfani, Lutye, Bavcar, van Lenthe, Brug and Cattaneo, 2011).

Table 2.7: Summary table for prevalence of stunting, overweight, obesity and wasting in infants, children and adolescents in developing regions

Author	Country	Sample size	Stunting %	Overweight %	Obese %	Wasting %
Schoeman *et al* (2010)	South Africa	332 222 411	13% 0-11m 25% 12-23m 25% 24-59m	11% 0-11m 5% 12-23m 1% 24-59m		
Pedro *et al* (2012)	South Africa	292 296	6% boys 2.7% girls	2.1% boys 10.5% girls	0.71% boys 3% obese	
Kruger, Pienaar, Coetzee (2013)	South Africa	419 397	4.53% boys 4.06% girls			
Mamabolo *et al* (2005)	South Africa	162		5%		
Popkin, Richards, Montiero (1996)	South Africa	2467	28.5% 3-6y	7.3% 3-6y		
Wolde, Berhan, Chala (2015)	Ethiopia	445	25.3% 7-14y	7.4% 7-14y	2.5% 7-14y	
Yadav, Gupta (2014)	Nepal	615	21.6 severe u/3 20.7 moderate u/3			18.2% severe 12.9% moderate
Tathiah *et al* (2013)	South Africa	963	9.2% primary school girls	9% primary school girls (11.1% overweight girls stunted n=81)	3.8% obese psg (22% of obese girls stunted (n=22)	
Motbainor, Worku, Kumie (2015)	Ethiopia	3964	14.2% severe (0-60m m+f) 37.6% moderate (0-60m m+f)			6.2% severe wasting 17.3% moderate
Qureshi *et al* (2014)	India	2162 6-23m 2340 24-59m 4502 6-59m				3.8% severe 21.9% moderate 0.59% severe 4.8% moderate 2.1% severe 13.1% moderate

2.6.4 The nutritional double-burden of disease in developing countries

The nutritional double burden of disease is becoming a major health problem in low and middle income countries, especially among children (Tzioumis and Adair, 2014). Sub-Saharan African countries with a high prevalence of childhood under-nutrition have a correspondingly high prevalence of adult under-nutrition, not indicative of the nutritional double-burden (Wojcicki, 2014). However, while stunting, under-weight and wasting caused by under-nutrition remains prevalent in South Africa and other developing countries (de Onis, Blossner, Borghi, 2011), the prevalence of overweight and obesity is escalating in South Africa (Shisana *et al.,* 2012). Studies conducted in South Africa suggest the existence of a nutritional double burden of disease, in which both under and over-nutrition are found in the same communities, households and even in individuals (Tzioumis and Adair, 2014). Evidence of the double burden of disease is being found in both urban and rural areas of the country (Kumani-Murage, 2013).

2.6.4.1 Potential causes of the double burden of disease

Successful catch-up growth achieved within the first two years of life in stunted children was related to a higher than standard BMI and body fat percentage at the age of five years (Pomeroy, Stock, Stanojevic, Miranda, Cole and Wells, 2014; Ong, Ahmed, Emmett, Preece, and Dunger, 2000). Evidence suggests that catch-up-growth-related overweight persists into adolescence and adulthood (Kruger, 2014). Poor early childhood growth has been suggested as a reason for the increasing burden of obesity (Ong *et al*., 2000). The long term outcomes of early life nutritional status are presented in Table 2.8.

Infection, diet quality and physical activity levels coupled with anaemia and other underlying factors that are associated with stunting and overweight may occur simultaneously in the same individual (Tzioumis and Adair, 2014). A nutritional double burden effect, which has been linked to the nutrition transition is the concurrent increasing prevalence of overweight women and under-weight children (Kruger, Steyn, Swart, Maunder, Nel, Moeng and Labadarios, 2012). Dieffenbach and Steyn (2012) have suggested that this problem is partly caused by easy accessibility to energy-dense foods, which are linked with adult overweight and poor accessibility to the nutrient-dense foods that are required for optimal child growth in the same households. In a study conducted in the South West border area of Texas, an area with high rates of poverty, obesity and household food insecurity, Sharkey, Nalty, Johnson and Dean (2012) found that very low food security was associated with increased energy, fat and added sugar consumption among children aged between six and eleven years. Micronutrient intake of calcium, sodium, potassium and vitamin D as well as dietary fibre among these children were found to be much lower than the recommended amounts for age (Sharkey, Nalty, Johnson and Dean, 2012).

Table 2.8: Chronic disease risks associated with poor early nutritional status.

Nutritional status	Health outcomes
Low birth weight	Decrease overweight, OR of 0.67 (95CI: 0.59-0.76), $p<0.001$ (Schellong *et al.,* 2012) Increase type 2 diabetes risk, OR of 0.77 (95%CI 0.70, 0.84) (Whincup *et al.,* 2008) Increased risk of T2 DM OR=1.83 (CI 1.37-2.45) $p<0.001$ (Forsen *et al.,* 2000)
High birth weight	increased risk of overweight (OR = 1.66; 95% CI 1.55–1.77), $p<0.001$ (Schellong *et al.,* 2012) Increased risk of metabolic syndrome HR= 2.19 (95% CI 1.25-3.82) (Boney *et al.,* 2005)
Overweight at 1 year (WAZ>+2 SD)	Increase DM risk OR = 4.2 (95% CI 1.1 to 16) $P<0.001$ (Barker 2004) Increase risk of premature death from CVD HR=1.96 (95% CI 1.23-3.12) $p<0.001$ (Barker 2004)
Obese at 1 year (WAZ> +3 SD)	Increase DM risk OR= 2.1 (95% CI0.5-7.9) $p<0.001$ (Barker 2004) Increase risk of premature death from CVD HR=1.36 (95% CI 0.82-2.26) $p<0.001$ (Barker 2004)
Stunting (8-11 years old)	Decrease fat oxidation (25 +- 2% compared with 34 +- 2% of energy expenditure; $p< 0.01$) (Hoffman *et al.,* 2000) Reduced resting energy expenditure compared with control $p<0.001$ (Hoffman *et al.,* 2000)
Marasmus survivors	Increased IGTT compared with kwash survivors OR =10.9 (95% CI 2.1–55; P <0.004) (Francis-Emmanuel *et al.,* 2014)
Rapid catch up growth in adolescence	Increase T2 DM risk OR 1.39 CI 1.21 to 1.61 $p<0.001$ (Forsen *et al.,* 2000)
Malnutrition in early gestation	Increased CVD risk OR of 3.0, 95% CI: 1.1 - 8.1) $p<0.01$ (Roseboom 2000)
Diabetic mother	Increased risk of overweight offspring OR = 1.4 (95% CI 1.1-2.0) (Gillman *et al.,* 2003)
Maternal obesity	Increase risk of metabolic syndrome in offspring HR=- 1.91 (95% CI 1.03-3.19) (Boney *et al.,* 2005)

South Africa is experiencing the nutritional transition from traditional lifestyles to more "Westernised" eating patterns and physical activity levels, affecting both rural and urban populations. The effects of the nutritional transition and double burden of disease include high rates of both under and over-nutrition.

2.6.4.2 The relationship between stunting and overweight in the context of double-burden South Africa

The results of the SAVACG study (1994) revealed that a quarter of South African children under the age of five years were stunted in 1994. It was also found that one in ten children was under-weight in this age group (SAVACG 1994). As the prevalence of under-weight was relatively low compared to the prevalence of stunting, it would appear that stunting is a more common problem for this age group. South African children suffer a higher prevalence of stunting than under-weight (Mamabolo, Alberts, Steyn, Delemarre-van de Waal and Levitt, 2005). It has been assumed that if a child is short for his or her age, he or she could be expected to have a lower weight for age if weight for height is to be maintained as normal. Stunting is far more prevalent than wasting in South Africa (Christian et al., 2013). However, the relatively low number of under-weight for age children among the high number of stunted children from this age group may indicate that stunting is actually more realistically associated with overweight for age. The mean WAZ was -0.32 (SD=1.20), but under-weight (WAZ<-2) affected only 7.2% (Christian *et al.,* 2013).

As early as 1996, Popkin, Richards and Montiero showed that the relative risk of overweight children being stunted was 2.6 suggesting a strong link between stunting and the risk of overweight among children. Almost a decade after Popkins *et al.* (1996) predicted the problems associated with stunting and overweight among South African children, Mamabolo, Alberts, Steyn, Delemarre-van de Waal and Levitt (2005) described concurrent rates of stunting and overweight in a population of children in the Limpopo province. These researchers found that among their sample of children, 17% of stunted children were under-weight, whereas 2% of non-stunted children were under-weight. Over-weight was highly prevalent in both stunted (26%) and non-stunted children (21%). The effects of under-nutrition during early childhood have been linked to chronic diseases of lifestyle, traditionally perceived as diseases affecting more affluent sectors of society.

Inadequate nutritional intake may cause an adaptive response which predisposes undernourished children to later over-weight and obesity. Survivors of childhood severe acute malnutrition have reduced insulin secretion and higher glucose intolerance, indicative that childhood under-nutrition may harm pancreatic β-cells, predisposing survivors of under-nutrition to later non-communicable diseases (Francis-Emmanuel, Thompson, Barnett, Osmond, Byrne, Hanson, Gluckman, Forrester and Boyne, 2014).

While chronic diseases of lifestyle typically affect adults, trends among South African children reveal that children and adolescents are now also at a high risk of developing these conditions. Pre-term birth and accelerated weight gain after 48 months has been associated with adult glucose intolerance, while accelerated weight gain during the first two years of life increased adult risk of insulin resistance, highlighting the importance of childhood nutritional status in adult disease risk (Norris, Osmond, Gigante, Kuzawa, Ramakrishnan, Lee, Ramirez-Zea, Richter, Stein, Tandon, Fall and the COHORTS group, 2015).

In a small cohort study, Martins, Hoffman, Fernandes, Naseimento, Roberts, Sesso and Sawaya (2004) showed that participants who were stunted during childhood gained more fat mass and had less lean body mass than their non-stunted counterparts by the time they reached adolescence ($p<0.05$). Stunted children had a statistically significantly higher mean body fat percentage than non-stunted children at baseline ($P<0.05$) (Martins *et al.,* 2004).

However, the relationship between stunting and other forms of malnutrition may not only be in the direction of overweight. Timaeus (2012) suggested that random errors in height measurements in children in South African longitudinal studies conducted between 1993 and 2004 may have exaggerated the association between stunting and overweight; asserting that under-weight is more likely in short children than tall ones when inclusion is corrected for cases where the recorded second measurement is improbable in comparison to the first measurement and predicted growth velocity. In this analysis, data was cleaned, removing any physiologically implausible Z-scores such as height for age less than -6 SD (Timaeus, 2012).

Thus it can be seen that although there appears to be a relationship between stunting and overweight, there is evidence to support the more intuitive relationship between stunting and wasting.

2.6.4.3 The relationship between stunting and wasting in South Africa

A study was conducted by Steenkamp *et al.* (2016) to describe the relationship between stunting and wasting among South African children with MAM. The prevalence of stunting and wasting were 58% and 13% respectively (Steenkamp *et al.,* 2016). It was found that 21% of the children sampled were both stunted and wasted, suggesting that the two conditions can occur simultaneously in the same individual, which may complicate intervention (Steenkamp *et al.,* 2016).

In an analysis of eight longitudinal anthropometric studies, Richard, Black, Gilman, Guerrant, Kang, Lanata, Molbak, Rasmussen, Sack, Valentiner-Branth and Checkley (2012) investigated the associations between wasting and stunting in early childhood. Analysis of the data showed that infants who were wasted at three, six or nine months were likely to recover before the first birthday. This would suggest that wasting is an acute and reversible condition. Infants who were stunted during the first year of life were unlikely to recover before twelve months of age. The implication is that stunting is a chronic condition with a poor rate of recovery (Richard *et al.,* 2012). The evidence appears to support the common belief that wasting is an acute condition while stunting is a result of chronic under-nutrition. However, it is more accurate to assert that wasting is acute in its duration and stunting, due to its poor likelihood of recovery, becomes a chronic condition over time. It has been demonstrated by Freemark (2015) that young children with SAM have significantly higher blood concentrations of cortisol and suppressed production of insulin-like growth factor-1 (IGF-1), resulting in bone growth retardation. During acute malnutrition, gluconeogenesis and lipolysis to supply glucose to the brain and vital organs is favoured over anabolic pathways (Freemark, 2015; Bartz *et al.,* 2014). This suggests that wasting and stunting occur simultaneously as a result of acute under-nutrition, but stunting remains as a chronic condition following recovery from wasting.

The strength of association between death and wasting, stunting and under-weight increased as Z-scores decreased. However, it was found that wasting is a stronger determinant of death than stunting or under-weight (Olofin *et al.,* 2013). A notable finding from this study was that the mortality risk was higher among severely stunted [HR= 5.48 (SD 4.62; 6.50)] children than moderately wasted children [HR= 3.38 (SD 2.86; 3.98)] (Olofin *et al.,* 2013). The strong association between wasting and mortality risk is one of the reasons that measuring MUAC has been favoured as an assessment of nutritional status in research. The planned bias incurred by using a single MUAC cut-value for six to 59 months and its implications for detecting mortality risk are explored in the next section.

2.7 MUAC AS A PREDICTOR OF MALNUTRITION

As mentioned previously, MUAC measures the circumference of the arm including bone, muscle, adipose and dermal tissues. The MUAC may therefore be used as an indirect method to assess the degree of wasting of fat and muscle stores in infants and young children (Briend, Khara and Dolan, 2015).

As previously mentioned, growth monitoring and promotion is defined by the Department of Health (2013) as "regular measurement, recording and interpretation of a child's growth in order to counsel, act and follow-up results with the purpose of promoting child health, human development and quality of life". Although specifically aimed at American children with special healthcare needs that predispose them to under-nutrition, the American Society for Parenteral and Enteral Nutrition (ASPEN) stresses the importance of incorporating routine screening for malnutrition into primary health care provided for children (Becker, Carney, Corkins, Monczka, Smith, Smith, Spear and White, 2014). The simplicity of MUAC makes it an ideal diagnostic tool for identifying malnutrition (Briend, 2012). The MUAC can be measured easily, and has been shown to be well understood by health workers and children's caregivers (Blackwell *et al.,* 2015 and is able to accurately identify malnutrition even with extremely limited training (Blackwell *et al.,* 2015). These factors allow for MUAC to be measured more frequently than WHZ. According to Briend and Zimicki (1986), MUAC should be measured monthly for optimal monitoring of nutritional status, which is more achievable than WHZ. The increased frequency of MUAC measurement aids in earlier identification of SAM, which may help in reducing the time between the beginning of malnutrition and the onset of complications (Briend, 2012).

However, there are growing concerns about the current MUAC cut-off values for identifying infants and young children with MAM and SAM. One concern is that such low cut-off values mean that children are extremely malnourished before they reach the threshold for intervention (Joseph, Rebello, Kullu and Raj, 2002). Although there is sufficient evidence that WHZ Z-scores and MUAC may be used as independent criteria for identifying cases of high-risk malnutrition (Briend, 2009), Laillou *et al.* (2014) found that the WHO-recommended MUAC cut-off values identified a significantly different set of young children as malnourished when compared with WHZ Z-scores. Ali, Zachariah, Shams, Vernaeve, Alders, Salio, Manzi, Allaouna, Draguez, Delhevalerie and Harries (2013) recognised that there was little overlap between the groups of children identified by either MUAC or WHZ Z-score as severely malnourished. It has been estimated that there is an overlap of 40% between WHZ and MUAC (WHO and UNICEF, 2009). However, in spite of the lack of overlap, their investigation in Bangladesh led these researchers to conclude that using MUAC alone is acceptable to identify SAM in children. Based on their results, Ali *et al.* (2013) recommend that a higher MUAC cut-off value might increase the number of children included in nutrition interventions, who are at a high risk of nutritional deterioration.

There has also been some concern regarding the use of a single MUAC cut-off value for children aged between six and 59 months. De Onis, Yip and Mei (1997) showed that MUAC is in fact age-dependent. It was found that older children within this age group tend to have higher mid-upper arm circumferences than younger children. This in turn leads to an under-diagnosis of wasting in older children and more diagnoses of wasting among younger children (De Onis, Yip and Mei, 1997). Furthermore, the risk of mortality decreases as age increases, making MUAC's ability to predict mortality risk biased towards younger children and not necessarily descriptive of mortality risk for the whole age group (De Onis, Yip and Mei, 1997).

2.7.1 The sensitivity and specificity of MUAC as an indicator of nutritional status

If MUAC is to be an effective screening tool for community nutrition use, it should not identify fewer children as malnourished than WHZ (Dasgupta, Sinha, Jain, Prasad, 2013). Fernandez, Delchevalerie and van Herp (2010) reported that MUAC had a sensitivity of 25% at the current 11,5cm cut-off. This information was obtained from 39 surveys including 34 937 children aged between six months and five years (Fernandez *et al.,* 2010). If policy were to change to having a single test for SAM, specifically either WHZ or MUAC, current cut-off values would result in different numbers of children being identified as SAM (Grellety and Golden, 2016). The MUAC alone would identify 55 or 19%, whereas WHZ alone would identify 61 or 18% as SAM (Grellety and Golden, 2016).

Sensitivity and specificity are aspects of great importance in developing tools for identifying malnutrition in the field (Joseph, Rebello, Kullu and Raj, 2002). Sensitivity refers to the accuracy of the tool in identifying the presence of the condition being investigated for, whereas specificity describes the ability of the tool to accurately identify individuals who have the condition under investigation. An overly sensitive tool loses specificity, therefore it becomes a problem of ensuring that the tool does not miss individuals who are malnourished, while at the same time preventing an overload of unwarranted cases, burdening already resource-constrained public health services (Joseph *et al.,* 2002).

Mogendi, De Steur, Gellynck, Saeed and Makokha (2015) conducted a study that included 156 Kenyan children aged between six and 59 months. This study tested the efficacy of MUAC in identifying malnourished children. The sensitivity, specificity, positive predictive value, negative predictive value, positive likelihood ratio and negative likelihood ratio were used as indicators of MUAC efficacy. The current MUAC cut off value of 12.5cm scored high values for these indicators, leading the researchers to conclude that MUAC can be used as a tool for identifying malnourished children at the current cut-off values (Mogendi *et al.,* 2015).

Shekhar and Shah (2012) however questioned the validity of the current MUAC cut off value of 11,5cm following the work of Fernandez *et al.* (2010). Shekhar and Shah included 346 under-weight children (WAZ<-2) between the ages of six and 59 months in their study. The resulting indicators of the performance of MUAC at different potential cut off values are presented in table 2.7. The implications of this study were limited by its inclusion of under-weight children only, and the study authors recommended that a similar study be conducted to test the validity of MUAC in a community setting (Shekhar and Shah, 2012). Shekhar and Shah (2012) concluded that 11.5cm is an appropriate MUAC cut off value however 12.0cm may be more suitable for predicting severe wasting. The sensitivity of MUAC at 11.5cm is 43.2%, which increases to 74.4% at 12.0cm. The specificity of MUAC at 11.5cm is 90%, which is reduced to 77.8% at 12.0cm.

Under-weight for age is defined as WAZ<-2 (WHO 2006). MUAC is usually used as a method of assessing wasting as an alternative indicator to WHZ (Briend, 2009). The WAZ is most commonly used as the indicator of child nutritional status, as health workers report that they are uncomfortable using weight and height in conjunction (Cloete *et al.,* 2013).

Dasgupta *et al.* (2013) used the same set of performance parameters to test the efficacy of MUAC as an indicator of malnutrition. However, their sample was purposefully designed to include an extremely high number of stunted participants (57% had HAZ<-3). At 12.0cm, MUAC had a sensitivity of 17.5% and a specificity of 96.3% (Dasgupta *et al.,* 2013). This means that MUAC was more sensitive at 11.5cm in the under-weight population than it was in the stunted population. Specificity was lower in the under-weight population at 11.5cm (Shekhar and Shah, 2012) than it was in the stunted population (Dasgupta *et al.,* 2013). Considering the high prevalence of stunting in South Africa (Shisana *et al.,* 2012), community testing of the sensitivity and specificity of MUAC may reveal important insights into the appropriateness of current cut off values. The lack of measuring equipment and skills to accurately weigh and measure children, further necessitates further investigation into alternative MUAC cut-off values for the Eastern Cape.

Balancing sensitivity and specificity is one of the many challenges facing researchers in developing useful tools for assessing nutritional status. This phenomenon is illustrated in the literature by Dasgupta, Sinha, Jain and Prasad (2013), who conducted research into the use of MUAC as a predictor for malnutrition in Madhya Pradesh, India. It was found that the recommended 11.5cm MUAC cut-off value for identifying SAM had a low level of sensitivity. Their concern was that current recommendations for MUAC cut-off values overlook a large number of children who are at risk of, or are already suffering from, SAM.

Ali *et al.* (2013) reported that 27% of their sample of malnourished children maintained their nutritional status over a period of three months of community-based management of acute malnutrition (CMAM) nutrition intervention (approximately 66% of the study participants' nutrition status improved from less than three SD of the standard to less than two SD for WHZ, illustrating the success of this intervention strategy). However, this result draws attention to the possibility that children in informal settings are at a higher risk of the adverse effects of malnutrition on growth. A possible solution is to prevent nutritional deterioration to the point of poor intervention outcomes from occurring altogether, by ensuring timely and appropriate access to healthcare interventions. Raising the MUAC cut-off threshold for identifying SAM may improve the chance of recovery by reducing the delay before intervention is initiated.

At 14.0cm, a child is very likely to be significantly malnourished. Between 14.0 and 15.0cm, the child may be malnourished, especially as the child gets closer to the fifth birthday (Shaw, 2015). The child's nutritional status is most likely to be reasonable is the MUAC is greater than 15.0cm (Shaw, 2015).

Raising the recommended MUAC cut-off value for identifying SAM from 11.5cm to 13.3cm as suggested by Laillou, Prak, de Groot, Whitney, Conkle, Horton, Un, Dijkhuizen & Weiringa (2014), or even as high as 15.5cm, as recommended by Dairo, Fatokun & Kuti (2012), results in a higher sensitivity of the tool. However the raised sensitivity results in a lower specificity. This was demonstrated by Dairo, Fatokun and Kuti (2012), who showed that "at 13.5cm cut off, the sensitivity of MUAC is 20%, and the specificity is 95.3%, with a Kappa of 16.7%. The receivers operating curve reveals an optimum cut off of 15.5cm with optimal but improved MUAC sensitivity of 80% and specificity of 53.5%" (p 143). Talapalliwar and Garg (2015) studied the sensitivity and specificity of MUAC cut-off values in Indian children. It was found that a MUAC cut-off value for SAM screening of 12.8cm was optimal. A 12.8cm cut-off had a sensitivity value of 50% and specificity of 90.8% (Talapalliwar and Garg, 2015). The current cut-off for SAM diagnosis of 11.5cm provided a sensitivity of 13.6% and specificity of 99.3% for the sample (Talapalliwar and Garg, 2015).

The MUAC is closely related to the risk of mortality (Mwangome, Fegan, Fulford, Prentice and Berkley, 2012; Garenne, Willie, Maire, Fontaine, Eekels, Briend & Van Den Broek, 2009). Therefore, it is a good predictor of nutritional outcomes. However, due to recent discrepancies across several countries, further investigation is warranted (Laillou *et al*., 2014).

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

Determining the nutritional status of populations is useful in designing effective nutrition interventions. The study sought to determine what the prevalence of stunting, wasting and overweight in Motherwell, NMBM among infants and children younger than two years old. Furthermore, the study aimed at testing associations between MUAC and WHZ to determine sensitivity and specificity of MUAC as predictor of malnutrition risk and develop malnutrition screening recommendations relevant to this population. This chapter describes the study design that was employed, aspects of the methodology including the instruments used, study population and sampling. This chapter also covers the validity, reliability and relevant ethical considerations.

3.2 STUDY DESIGN

This descriptive study was undertaken using a cross sectional design. The study was analytical, requiring quantitative, empirical data. This design was appropriate as the study aimed to synthesise a profile of nutritional status. However, it is a limited design as no inferences could be made on the growth patterns of the children in the population. This would have required a longitudinal study design. Shisana *et al.* (2012) made use of a cross sectional design to describe the nutritional status of South Africans in the SANHANES-1 study.

A survey-based approach was used to obtain data. Surveys using questionnaires can provide information directly, especially factual data such as household size or medical history. However, the sample needed to be of adequate size and to be representative of the study population in order to avoid bias. Structured questionnaires were successfully used by Schoemann *et al.* (2010) to determine the severity of adverse social, cultural and health conditions in rural areas of South Africa.

3.3 STUDY POPULATION

The population that was investigated in this study was infants and children younger than two years old, residing in Motherwell, in the Nelson Mandela Metropolitan Municipality Health District. Motherwell has an area of approximately 25.86km^2 and a population of 140 351 people (Census 2011). The population is 52.48% female, and

47.52% male. People of black African ethnicity constitute 99.2% (n=139229) of the population (Census 2011). The population of children younger than two years in Motherwell was 5817 in 2016 (Personal communication Nutrition Manager NMB). The community is comprised of lower income residents. Six clinics provide primary healthcare services in Motherwell (DHIS). These clinics are Motherwell Community Health Centre (CHC), Motherwell NU11 clinic, Motherwell NU2 clinic, Motherwell NU8 clinic, Ikamvalihle clinic and Wells Estate clinic.

3.4 SAMPLING

The study sample was obtained from infants and children younger than two years living in Motherwell. The sample represented the ethnic and socio-economic characteristics typical of the study population. A sample was drawn from the community of Motherwell in the Eastern Cape using a convenience sampling method. Convenience sampling or accidental sampling is a form of non-probability sampling (Profetto-McGrath, Polit and Beck, 2010). Using this method, the sample was obtained on the basis of availability or accessibility (Ellsion, Farrant and Barwick, 2009). This method may be used when there is little evidence available on a particular subject.

Potential study participants were identified at clinics and crèches serving the Motherwell catchment area. The list of clinics and crèches used for sampling is given in Table 3.1. The distribution of clinics and crèches helped to ensure a sample representative of the Motherwell area (Figure 3.1).

Table 3.1: Sites selected for sampling in Motherwell, NMBHD

Convenience sampling sites in Motherwell, NMBHD
Ikamvalihle Clinic
Motherwell CHC
NU1, Zukhanye Creche
NU2 Clinic
NU2 Qaqa Creche
NU2, Feetjies Creche
NU2, Futurekids Creche
NU2, Tiny Buddies Creche
NU5, Cumani Preschool
NU5, IKHWEZI Lompso CC
NU5, Likhaya Creche
NU5, Mbalentle Creche
NU5, Sinakho Creche
NU7, Jesus Dominion Creche
NU10, Ikamvalethu Christian Day Care
NU11 Clinic
NU11, St Mary Magdeline Creche
Wells Estate Clinic
Wells Estate, Good Hope Creche
Wells Estate, Zusalcke Creche

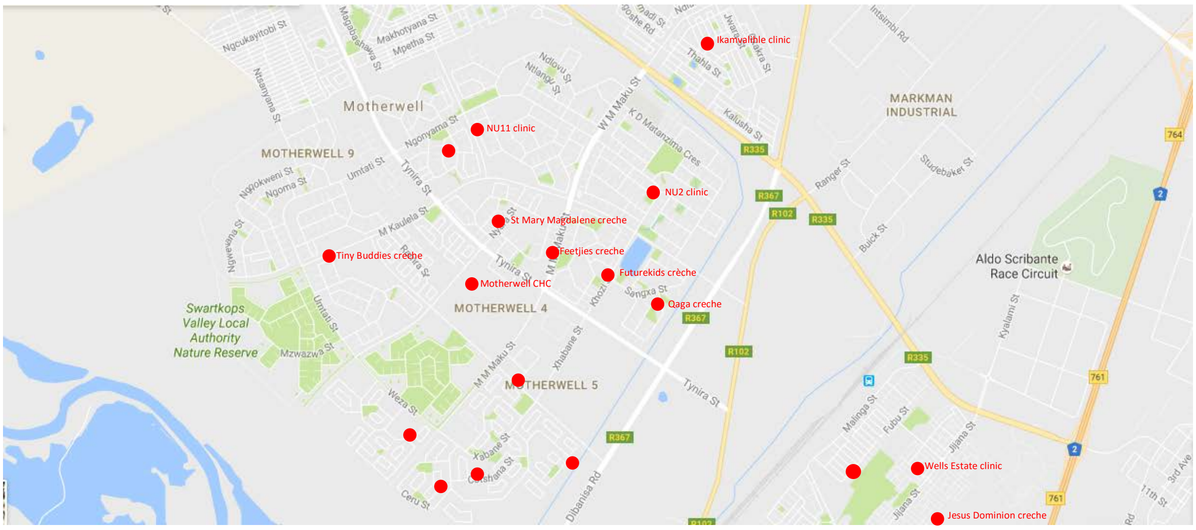

Figure 3.1: Distribution of sampling sites in Motherwell, NMBHD

This method allowed for sampling to occur according to a systematic schedule. A list of crèches servicing infants and children younger than two years old was obtained from a non-governmental organisation operating in the area. Quantitative data on anthropometric measurements was collected from study participants.

3.4.1 Inclusion and exclusion criteria

The inclusion and exclusion criteria chosen for the selection of study participants are listed as follows:

Inclusion criteria:

- Any children below the age of two years residing in Motherwell;
- Children could only be included in the sample if their parents or guardians gave consent;
- Both male and female infants and children, regardless of socio-economic status; and
- Black African infants and young children were included in the study to create a homogenous study sample and prevent bias in the interpretation of the results.

Exclusion criteria:

- Children who are older than 24 months at the time of measurement;

- Children who have a WHZ, HAZ, WAZ or MUAC measurement above or below five standard deviations of the sample mean;
- Children with incomplete anthropometric data available were excluded;
- Children who have foetal alcohol syndrome (FAS), cerebral palsy (CP), or history of tuberculosis (TB) were excluded from the study as these conditions affect nutritional status; and
- Children of ethnicity other than African, including coloured, white or others, were excluded in order to create a homogenous sample which is representative of the study population.

The Road to Health Booklet was presented by participants' caregivers upon anthropometric examination in order to screen for these factors.

3.5 METHODS

3.5.1 Research instruments

Scales

The weight of infants and young children is monitored as a measure of growth. Weight was measured using a Nagata BW-2010 infant scale (capacity: 20kg x 10g). This scale is used to determine the weight of infants and young children. As infants have poor motor control, infant scales are designed with a bucket to measure the infant's weight recumbently. Recumbent weight is an appropriate measurement for children under two years of age (Centre for Disease Control, 2007). This model of infant scale is used by the South African Department of Health for growth monitoring.

Infantometers

Length was measured using an infantometer. A Seca infantometer with a movable foot piece was used for subjects seen at clinics, while a foldable portable Seca infantometer was used during crèche visits. Length was recorded in centimetres (cm) to the nearest 0.1cm (1mm).

MUAC tapes

Non-stretch MUAC tapes were used in the study. Dairo *et al.* (2012) found that MUAC has poor sensitivity in identifying wasting in children younger than two years using current cut-off values. However, Burden *et al.* (2001) found that MUAC was a reliable tool for identifying malnourished patients when compared with other markers of malnutrition ($p<0.05$). The MUAC is recorded to the nearest 0.1cm (1mm).

Data collection sheet

A data collection sheet was designed for the purposes of this study. An example of the data collection sheet can be found in Appendix A. This tool was printed on A3 sized sheets of paper and took the form of a table. Each data collection sheet was marked with the date and the name of the site at which data collection took place. The data collection sheet took the form of a grid. Each study participant was identified with a unique eight-digit code based on their initials and date of birth. The participant codes helped to prevent repetition. Data obtained was coded (see Appendix A) into categories of answers. Data on the ethnicity, gender and date of birth was obtained using the data collection sheet. Gender and ethnicity aided in creating a homogenous sample. Using the participants' date of birth in conjunction with the date they were measured allowed researchers to calculate their age in days, increasing accuracy and validity of measurements. Weight, length and MUAC measurements were recorded on the data collection sheet. Particulars of participants' history were also recorded, including number of siblings, parity of the mother, TB and HIV status (recorded as RVD and coded to protect participant confidentiality). The data collection sheet also included the Community Childhood Hunger Identification Project (CCHIP) questionnaire. The CCHIP questions were printed on the bottom of the collection sheet to aid fieldworkers in accurately asking the questions. The questions were answered with simple affirmation or negation. The data collection sheet was piloted before it was implemented in the study and no changes were made to it.

CCHIP questionnaire

The Community Childhood Hunger Identification Project (CCHIP) was a survey which took place in the United States between 1992 and 1994. The questionnaire developed is used as a model for measuring hunger in low income households (Wehler, 1995). Frongillo *et al.* (1997) found that CCHIP questionnaire-based measures of household food insecurity had good specificity and excellent sensitivity when compared with the criterion measure and therefore are valid in screening for hunger and food insecurity. Please refer to Appendix A for the CCHIP questionnaire which describes household level food insecurity (Labadarios *et al*., 2011). The questions are presented in Table 3.2.

Table 3.2: CCHIP questions

Question 1: Does your household ever run out of money for food?
Question 2: Do you ever rely on a limited number of foods to feed your children because you are running out of money to buy food for a meal?
Question 3: Do you ever cut the size of meals or skip meals because there is not enough money for food?
Question 4: Do you ever eat less than you should because there is not enough money for food?
Question 5: Do your children ever eat less than you feel they should because there is not enough money?
Question 6: Do your children ever say they are hungry because there is not enough food in the house?
Question 7: Do you ever cut the size of your children's meals or do they ever skip meals because there is not enough money to buy food?
Question 8: Do any of your children ever go to bed because there is not enough money to buy food?

WHO Anthro

WHO Anthro is software that was developed to facilitate the application of the WHO child growth standards in individuals and populations of children up to the age of five years (WHO, 2007). A nutritional survey module forms part of the specific functions of the programme (WHO, 2007). Alasfoor and Mohammed (2009) used WHO Anthro to compare NCHS/WHO estimates of malnutrition and obesity to updated WHO 2006 estimates using a common sample. These researchers found that using the WHO Anthro software, the new WHO 2006 growth standard values corrected the underestimations of malnutrition found using the NCHS/WHO standards (Alasfoor and Mohammed, 2009).

3.5.2 Pilot study

A pilot study was conducted using 14 infants and young children from Zwide Pre-primary School Crèche to test and validate the methods, data collection tools and equipment used in the study. It was found that the CCHIP questionnaire would be difficult to complete in the crèche setting, and it was decided that clinics would be used to obtain the data on food security. The study procedures were found to be satisfactory from the results of the pilot study and no other changes were made to the methods.

3.5.3 Study procedures

A data collection sheet was completed by trained fieldworkers. These fieldworkers included dieticians, dietetics students from NMMU and community health workers from Motherwell Community Health Centre to assist with translation. Fieldworkers gathered information on the demographic characteristics and anthropometric measurements of the study participants. Fieldworkers also obtained information on household food security using a validated questionnaire (CCHIP), which can be found in Appendix A.

The methods for accurately measuring anthropometric information in infants and young children followed procedures suggested by the Centre for Disease Control (2007) and WHO (2006) and is described in 3.3.2. Students collecting data for use in the study received regular training and conducted their work under the supervision of qualified dietitians. Techniques for accurately measuring the height, weight, mid-upper arm circumference of infants and young children were taught and demonstrated.

Data was collected over a period of four months, beginning in November 2015 and ending in February 2016. Infants and young children under the age of two years were recruited for the study provided informed consent was given by their caregivers. Each infant or young child included in the study received an identification number synthesised from their initials combined with their date of birth. Trained field workers measured and recorded the anthropometric information of the study participants using standardised, calibrated measuring equipment and procedures. Anthropometric and demographic data was recorded and captured using WHO Anthro software and Excel spreadsheets respectively. The captured data was then cleaned according to set guidelines (WHO 2006).

3.5.3.1 Measuring techniques

Study participants were weighed and measured using standardised techniques outlined by the Centre for Disease Control (2007) for determining recumbent height, weight and MUAC. These are appropriate measurements for children under two years of age (Centre for Disease Control, 2007). Parallax is the phenomenon which occurs when observers of measurements record an erroneous measurement due to incorrect viewing angles. This was avoided (and the accuracy of measurements improved) by assessing measurements at eye level. All measurements were performed on the left hand side of the body, unless a confounding factor such as an amputation or cast made this impossible. All measurements were recorded to the nearest 1mm.

Procedures for correctly measuring anthropometric indicators were followed to ensure reliability of the data. The child's caregiver removed the infant's outer clothes. The field worker then turned the scale on, placing a clean Chux pad on the scale. The infant was then placed on the centre of the scale, allowing the weight reading to settle then the weight in kilograms (kg) was recorded to the nearest 0.01kg (10g).

Length was measured using an infantometer. This process required two research personnel for accuracy and involves the caretaker or parent to ensure justice to the infant. The infant's outer clothes were removed, and a clean Chux pad was placed on the infantometer length board. The child was positioned with the feet orientated toward the movable foot piece with the head resting against the stationary head piece. One researcher supported the head and recorded the measurement while the other positioned the feet and examined the length measurement. Infants may become agitated in a recumbent and vulnerable position, so it was advised that the infant's caretaker position her or himself between the recorder and examiner (Centre for Disease Control, 2007). The infant's back and legs must be straight, with the sole of the foot perpendicular to the length board for a reading to be accurate. Extremely uncomfortable children may be recorded with only one straight leg. A gentle stroke along the inside of the infant's foot may help to get it into the correct position (Centre for Disease Control, 2007). The foot piece was shifted up against the infant's feet to take the measurement. The length was recorded in centimetres (cm) to the nearest 0.1cm (1mm).

The MUAC was measured using a non-stretchable measuring tape. The procedure began with the researcher standing on the left hand side of the infant or young child, the infant's weight evenly distributed, shoulders relaxed and left arm hanging freely at the side. Arm circumference and skinfold measurements were taken on the left side of the body. The choice of which side to measure (right or left) matters little to accuracy and precision; however, the left-hand side is used more often (de Onis, 2004). The acromion process is found at the end of the shoulder and marked with a cosmetic pen. From this point, a tape measure was placed along the length of the upper arm to find the numerical midpoint. The midpoint was marked with a cosmetic pen. The infant's arm was moved into a position where it was bent perpendicularly at the elbow, palm facing upward. The circumference around the infant's arm at the marked midpoint was measured and recorded to the nearest 0.1cm (1mm).

Community care givers and dietetic students from Nelson Mandela Metropolitan University (NMMU) were given intensive training and retraining throughout the duration of the study to ensure accuracy of the data. Weight was measured using calibrated baby scales, and height was measured using recumbent length boards. Mid upper arm circumference was measured using standard MUAC tapes for children.

3.5.3.2 Data categories

The raw data was divided into clusters according to various categories, as shown in table 3.3. Gender was divided into male and female clusters of participants. The sample was categorised into two clusters according to birth weight. Participants with a birth weight of less than 2500g were placed into the low birth weight cluster, while participants with a birth weight of greater or equal to 2500g were placed into the normal birth weight cluster (United Nations Children's Fund and World Health Organization, 2004). Participants' ages were clustered as groups 0-2 months, 3-5 months, 6-8 months, 9-11 months, 12-14 months, 15-17 months, 18-20 months, 21-23 months (WHO and UNICEF, 2009). Anthropometric findings were categorised according to clusters presented in table 4.1. Children with a weight for height Z score of less than -3 SD were classified as SAM (WHO and UNICEF, 2009). The WHZ Z scores of less than -2 SD but greater than -3 SD were placed into the MAM cluster (WHO and UNICEF, 2009). The WHZ Z scores of greater than -2 SD were classed as normal (WHO and UNICEF, 2009). The WAZ Z scores greater than +2 SD were classed as overweight (Wang and Chen, 2012). Weight for age Z scores of less than -3 SD were placed in the severely under-weight for age cluster (WHO and UNICEF, 2009). The WAZ Z scores between -3 SD and -2 SD were placed in the under-weight for age cluster (WHO and UNICEF, 2009). Weight for age Z scores between -2 and +2 SD were classed as normal. Height for age Z scores of less than -3 SD were clustered as severely stunted while HAZ Z scores of between -3 and -2 were clustered as stunted (Wang and Chen, 2012; WHO and UNICEF, 2009). The HAZ Z scores of greater than -2 were clustered as normal. A MUAC measurement of >11.5cm was used to place a participant in the SAM cluster (WHO and UNICEF, 2009). A MUAC measurement of <12.5cm was used to place a participant in the MAM cluster (WHO and UNICEF, 2009). Participants with MUAC measurements of >12.5cm were placed in the normal MUAC cluster (WHO and UNICEF 2009). Scores obtained from the CCHIP questionnaire were grouped according to hungry (CCHIP score of greater than five), at risk of hunger (CCHIP score of one to four) and food secure (CCHIP score of 0) clusters (Lewit and Kerrebrock, 1997).

Table 3.3: Anthropometric categories and clusters

WAZ SD	**HAZ SD**	**WHZ SD**	**MUAC Category**
<-3	<-3	<-3	SAM
<-2	<-2	<-2	MAM
<-1	<-1	<-1	Normal
-1 to +1	-1 to +1	-1 to +1	
>1	>1	>1	
>2	>2	>2	
>3	>3	>3	

3.6 ANALYSIS

This study also made use of correlation-based research methods. Correlational statistics were employed to analyse relationships between anthropometric indicators of nutritional status. Variables that were not being tested for by the study could account for apparent correlations. The existence of relationships does not mean that relationships are causal. However, findings may lay the foundations for future research into associations.

Anthropometric data was used to calculate Z scores for WHZ, WAZ and HAZ using WHO Anthro software. Categorical data from the nutritional survey questionnaire was captured on a Microsoft Excel spreadsheet.

Data cleaning criteria are used to exclude extremely high or low values from the sample collected, as presented in Figure 3.2. These outlier values are likely to be due to measurement error and to influence the accuracy of the data distribution (Crowe, Seal, Grijalva-Eternod and Kerac, 2014). For the purposes of this study, data cleaning criteria according to WHO (2006) was applied. According to these criteria, WFL observations that fell above +5 SD and below -5 SD were excluded from the sample before the growth standards were developed.

Infants and young children whose measurements were incomplete, missing either a weight, length or MUAC measurement, were removed from the study. Participants of ethnicity other than African, including coloured, white or others, were excluded in order to create a homogenous sample that is representative of the study population.

Symmetric distributions were developed using the median weight from the sample. The cleaned data was then divided into two groups, one set containing values below the median weight and the other containing the values above the median measurement. These two sets can then be mirrored to recreate symmetrically distributed values for statistical analysis.

Flagging

The software flags out in purple any extreme, potentially incorrect or out-of-range values. The following lower and upper bounds have been fixed to identify these extreme or potentially incorrect z-score values.

Indicator	Lower bound	Upper bound
WHZ	-5	+5
HAZ	-6	+6
WAZ	-6	+5
BAZ	-5	+5

These default boundary values can be changed (if needed) in the *Variable view*.

Figure 3.2: An example of a computer program which identifies outliers in the data (WHO Anthro)

Descriptive statistics, i.e. frequencies and percentages, were used to describe outcome of categorical data. The Pearson correlation co-efficient (*r*) and Spearmans rank co-efficient were used to measure the strength or degree of the relationship between variables and to identify the significance of the correlation between variables (p=0.05). The strength of an association between two variables is often measured using either Spearmans's rank correlation co-efficient (r_S), or Pearson's correlation co-efficient (r) (Hauke and Kossowski, 2011). Spearman's rank correlation co-efficient enables researchers to measure the degree to which variables are related as described by ranked or ordinal data. Spearman's rank correlation is essentially a special case of Pearson's correlation co-efficient (Hauke and Kossowski, 2011).

T-tests were used to compare anthropometric data from different birth weight categories. T-tests are used for testing hypotheses using only two treatments. (Gravetter and Wallnau, 2009).

Cohen's d is a method of measuring effect size. Measuring effect size provides the magnitude of the treatment effect, regardless of the sample size used (Gravetter and Wallnau, 2011). Cohen's d statistic was used to determine whether differences in variables between gender categories were statistically significant.

The chi-square (Chi^2) is a statistical test used to evaluate the relationship between two variables (Gravetter and Wallnau, 2011). This test was used to determine whether differences in age categories were statistically significant.

The Scheffe test is a post-hoc test used to evaluate the significance of the difference between any two treatment conditions (Gravetter and Wallnau, 2011). This statistical test carries the smallest risk of a type I error occurring (Gravetter and Wallnau, 2011). Type I error refers to an error in hypothesis testing, in which a null hypothesis is rejected, when the treatment really has no effect (Gravetter and Wallnau, 2011). This statistical test was used to determine whether MUAC measurements were significantly different between age categories. The Scheffe test was similarly used to test whether WAZ observations differed significantly between age categories.

The sensitivity of a clinical test refers to its ability to correctly identify the presence of the condition being tested for (Lalkhen and McClusky, 2008). This was used to determine whether alternative MUAC cut-off values were able to identify children affected by wasting.

Specificity refers to the ability of a clinical test to correctly identify when a condition is absent (Lalkhen and McClusky, 2008). This test was used to determine whether alternative MUAC cut-off values identified healthy children as not acutely malnourished, ensuring that minimal false positives occurred.

3.7 Validity and reliability

3.7.1 Validity

Face validity

Face validity was strong as the anthropometric measurements chosen form part of routine growth monitoring and promotion, and are the same measurements recommended by the WHO.

Content validity

Standard measuring equipment was used to obtain anthropometric information from participants. Infant scales were used to measure weight and a length board, infantometers, were used to determine length as the participants were infants, as recommended by the WHO (2006) and CDC (2007). The CCHIP questionnaire was used to assess household food security. This questionnaire has been used before, and the questions are carefully phrased to ensure that they did not influence the respondent’s answer. Health information such as HIV status and medical history was obtained from the RtHB, an official document. This was to reduce errors of communication or uncertainty.

3.7.2 Reliability

Weights, lengths and MUAC were measured using the same equipment to ensure consistency. The data collection sheet and measuring techniques were pilot tested prior to the study. This ensured that the data collected was accurate. Anthropometries were calculated using WHO Anthro software, where all children assessed had their Z-scores calculated using the “recumbent measurement” adjustment factor, which ensured consistency in findings. WHO 2006 data cleaning criteria were applied, removing individuals from the study whose anthropometric indicators lay outside of predetermined specifications. This ensured that outlying data points, which are more likely to be due to measurement or coding errors than physiological possibility, would not influence the data.

Internal reliability

This study made use of few fieldworkers, who were selected based on their experience and previous training as dietetics students and dieticians. This helped to ensure consistency in measurement accuracy. The same measuring equipment was used to assess nutritional status, so any errors due to measurement equipment would theoretically be consistent.

3.8 ETHICAL CONSIDERATIONS

Ethics approval was obtained from the Nelson Mandela Metropolitan University (NMMU) Research Ethics Committee (Human). The ethics approval number assigned was H15-HEA-DIET-002. The research proposal was approved by the Department of Health (Bhisho) and National Health Research Database, and the research project catalogued by the National Health Research Database. Permission to perform the study and to make use of NMBHD anthropometric equipment was obtained from the gatekeeper, the Clinical governance manager, NMBHD and INP Manager NMBHD.

Ethical considerations are important when asking potentially invasive questions.

Bell (2008) identified a set of principles that intersect human rights concerns and research ethics. These principles include respect for human dignity, informed consent, individual autonomy, equality, privacy and confidentiality, freedom of expression, access to information and justice. The philosophies of non-maleficence and benevolence directed and underpinned the intentions and actions of this research project. All procedures adhered to the ethical principles detailed by the Declaration of Helsinki (World Medical Association, 2008). The principles of Autonomy, Non-maleficence, Beneficence and Justice were maintained as follows:

Autonomy

Participation in this research was voluntary. As the study participants were infants, consent was obtained from their caregivers for participation. Where possible, participants were asked whether they agreed to have their measurements taken in cases of older children, however, the group under study did not yet have the cognitive development required for understanding confidentiality. Where infants and children became upset from the procedures, the researchers did not force the infant or child to participate. No participants were forced to take part in the study and no hidden data collection took place. The right of participants to withdraw from the study was clearly explained to participants before they were included in the study. All names were kept confidential, and participants' confidentiality was protected using an eight-digit code for identification. Therefore, no names or personal identifying information was captured onto the Excel spreadsheet.

Non-maleficence

Methods used ensured participant anonymity was protected. Participants' names were not included in the data collection or on the exported Excel spreadsheet and no personal identifying information was recorded. Participants will not be harmed by the publication of the findings of the study.

Beneficence

The aims of the study were explained to participants. The results of the study were reported to the Eastern Cape Department of Health, and will be communicated to health workers in Nelson Mandela Metropolitan Municipality.

Justice

The Human Rights of each participant were respected throughout the study.

All children seen at GMP sites were be given equal and non-discriminatory access to the full spectrum of services offered at these sites, and no child was excluded from health services rendered on the basis of inclusion or exclusion in the study. Infants and young children were screened for nutritional problems, and referred for the appropriate nutrition intervention according to national and provincial health department policies when required (Department of Health, 2013 b). Feedback on the nutritional status of the study participant was given to the caregiver of the participant immediately upon completion and interpretation of the measurements. Interpretation of nutritional status and appropriate nutritional interventions were carried out as required.

Ethical considerations were adhered to for the duration of the study, especially as this is a vulnerable population. Participation in the study was voluntary. All information pertaining to the study was explained orally and in writing, in English and isiXhosa. As study participants were children, written informed consent was obtained from participants' caregivers before inclusion in the research. The Road to Health Book carried by the caregivers of all infants and children younger than five years of age is intended for use by health workers, and is presented willingly by the caregiver to the health worker upon request. This document serves as a recording tool for health related activities including regular growth monitoring and promotion. Participant information was kept confidential. Participants received an eight-character identification code in order to protect their identities. The objectives of the study and methods for anthropometric measurements were explained to caregivers. Questionnaires included non-threatening questions and any questions pertaining to ethnicity or socio-economic status were only required to ensure that the data collected are from a sample representative of the Motherwell area. The results of the study will be disseminated at future growth monitoring and promotion activities performed in the community under observation. Screening tools that result from the study will be explained to and used by community health workers and students of NMMU, ensuring that all stakeholders benefit from this research.

There are no known conflicts of interest to declare.

3.9. CONCLUSION

The methods used in this study were designed to describe anthropometric measurements, demographic information, information on participants' medical history and food security data. Data cleaning took place according to WHO 2006 cleaning criteria in order to ensure that the findings from the study are valid and accurate. Statistical methods including descriptive statistics and inferential statistics like linear regression, sensitivity and specificity were used to identify associations between demographic indicators, health indicators, anthropometric weight for age (WAZ), height for age (HAZ), weight for height (WHZ) Z-scores and MUAC measurements as well as to determine sensitivity and specificity of MUAC as a predictor of malnutrition risk and to develop malnutrition screening recommendations relevant to this population.

CHAPTER 4

RESULTS

4.1 INTRODUCTION

This chapter describes the demographic information of the study sample and the anthropometric findings in terms of nutritional indicators including weight for age (WAZ), length/height for age (HAZ), weight for height (WHZ) and MUAC measurements. Correlations between these indicators are described. Correlations between MUAC and WHZ were used to develop acute malnutrition MUAC cut-off value recommendations specific to the Motherwell population. The sensitivity and specificity of these recommendations were tested to ensure that they are able to identify malnutrition accurately without excluding at risk cases. Associations between malnutrition and birth weight were investigated, as well as the associations between HHFS and the nutritional status of children in Motherwell, NMB to reflect on possible causes of malnutrition in this population.

4.2 DESCRIPTION OF THE STUDY SAMPLE

A total of 400 participants were retained as the final sample, having satisfied the criteria for inclusion in the study. Three records were deleted as they had WAZ, WHZ or HAZ Z-scores <-5 (WHO 2006). Six records were deleted as they had a WAZ, WHZ or HAZ Z-score >+5 (WHO 2006), according to recommended data cleaning criteria. One record was deleted as no height was recorded.

The sample (n=400) was thus homogenously (100%) of African ethnicity. The sample was made up of 50% (n=199) male participants, and 50% (n=201) female participants. The mean participant age was 9.78 months (SD=6.13). The mean female age was 9.75 months and mean male age was 9.78 months. There was no significant difference between the ages of male and female participants (p=0.53).

As illustrated in Table 4.1, 20% (n=79) of participants were between the ages of three and five months. Eighteen percent (n=71) of the children sampled were between six and eight months old. Fifteen percent (n=60) were between nine and eleven months old. Sixty-five percent (n=259) of the sampled children were between the ages of zero and 11 months old, while 35% (n=141) were between twelve and 23 months old.

Table 4.1: Distribution of participant age (n=400)

Age category Months	Number of children N	Percentage %
0-2	49	12
3-5	79	20
6-8	71	18
9-11	60	15
12-14	50	13
15-17	33	8
18-20	39	10
21-23	19	5
Total	400	100

4.3 THE PREVALENCE OF UNDERWEIGHT, STUNTING AND WASTING AND OVERWEIGHT IN MOTHERWELL

4.3.1 Underweight

Of the total sample, the mean WAZ Z-score was +0.44 (SD=1.26). The WAZ central tendency and distribution according to age categories is presented in Table 4.2. The age group with the greatest variance in WAZ was among infants aged three to five months (SD=1.44).

Table 4.2: WAZ central tendency and dispersion of the total sample (n=400) by age category

Age	N	Mean	SD	Minimum	Q1	Median	Q3	Maximum
0-2	49	-0.08	1.06	-3.81	-0.48	-0.07	0.70	1.51
3-5	79	0.35	1.44	-4.21	-0.57	0.33	1.12	4.68
6-8	71	0.39	1.19	-2.07	-0.40	0.34	1.24	2.68
9-11	60	0.55	1.31	-2.31	-0.37	0.65	1.45	4.06
12-14	50	0.88	1.00	-1.90	0.22	0.73	1.31	3.15
15-17	33	0.38	1.42	-2.32	-0.76	0.33	1.52	3.28
18-20	39	0.77	1.24	-2.91	0.22	0.87	1.38	3.50
21-23	19	0.35	1.05	-0.92	-0.23	0.02	0.86	2.90

WAZ scores among the male participants are presented by age category in Table 4.3. The age category with the lowest mean WAZ of -0.21 (SD=1.2) was observed in infants zero to two months. The highest mean WAZ was 0.90 (SD=1.02) in the 12 to 14 month age category.

Table 4.3: WAZ central tendency and dispersion Z scores of male participants by age category (n=199)

Age	N	Mean	SD	Minimum	Q1	Median	Q3	Maximum
0-2	25	-0.21	1.20	-3.81	-0.54	-0.10	0.47	1.51
3-5	33	0.33	1.52	-4.21	-0.15	0.61	1.06	3.29
6-8	40	0.12	1.23	-2.07	-0.78	-0.01	1.03	2.63
9-11	29	0.42	1.46	-2.31	-0.55	0.46	1.46	4.06
12-14	24	0.90	1.02	-1.90	0.25	0.79	1.65	2.44
15-17	20	0.25	1.55	-2.32	-1.10	0.05	1.38	3.28
18-20	18	0.86	1.37	-1.71	-0.05	0.85	1.68	3.50
21-23	10	0.25	0.94	-0.83	-0.14	-0.03	0.36	2.52

The central tendency and dispresion of WAZ scores among female participants is presented in Table 4.4. The age group with the highest mean WAZ was the six to eight month category (0.75; SD=1.05). The lowest mean WAZ score was found in the zero to two month age category.

Table 4.4: WAZ central tendency and dispersion Z scores of female participants by age category (n=201)

Age	N	Mean	SD	Minimum	Q1	Median	Q3	Maximum
0-2	24	0.06	0.81	-2.19	-0.17	0.19	0.72	1.24
3-5	46	0.35	1.39	-1.99	-0.67	0.07	1.14	4.68
6-8	31	0.75	1.05	-1.28	0.08	0.64	1.36	2.68
9-11	31	0.66	1.15	-1.23	-0.17	0.79	1.44	3.15
12-14	26	0.71	0.99	-1.52	0.22	0.73	1.21	3.15
15-17	13	0.57	1.22	-1.30	-0.67	0.89	1.53	2.62
18-20	21	0.69	1.16	-2.91	0.23	0.87	1.32	2.33
21-23	9	0.46	1.20	-0.92	-0.31	0.33	0.99	2.90

One percent (n=3) of the study participants were severely underweight for age (WAZ<-3). Two percent (n=7) of the children included in the study were underweight for age (-3≤WAZ≤-2). Male participants were more likely to be underweight for age than female participants (RR=2.52), however this increased risk was not significant at the p=0.05 level, and therefore males were not at a significantly higher risk of underweight than females (Figure 4.1).

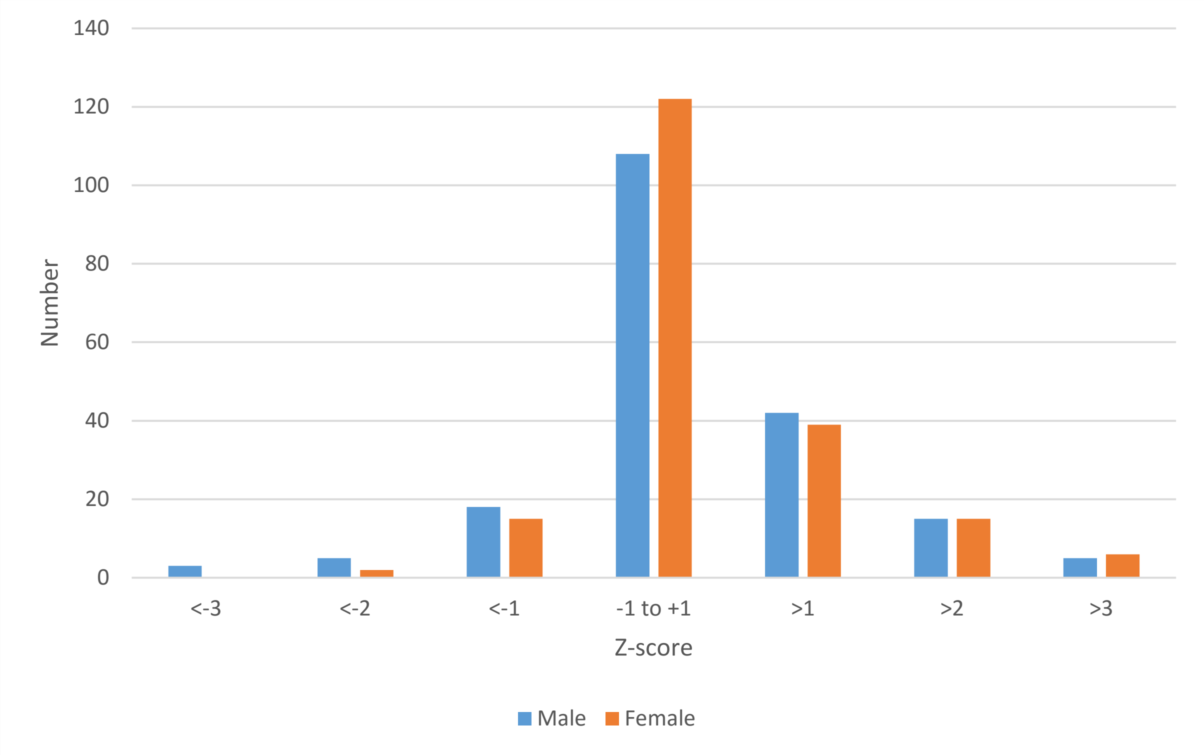

Figure 4.1: Weight for age frequency and distribution (n=395)

The mean WAZ and weight for males and females are compared in Table 4.5. Despite no significant differences in the age of participants as previously reported, the mean weight (in kg) was significantly higher for male compared to female participants (p=0.018). However, the difference was, according to Cohen's d, of small practical importance. There were no significant differences between male and female mean WAZ scores.

Table 4.5: Anthropometric measurements central distribution and T-tests by gender category (n=399)

Gender		n	Mean	SD	Difference	p-value	Cohen's d
Weight (kg)	Male	199	9.19	2.59	0.60	0.018*	0.24
	Female	200	8.58	2.49			
WAZ	Male	196	0.34	1.36	-0.19	0.135	0.15
	Female	199	0.53	1.16			

*Significant to p<.05

4.3.2 Stunting

Of the total sample, the mean HAZ Z-score was -0.24 (SD=1.34). The distribution of HAZ scores is presented by age category in Table 4.6. The 15 to 17 month age category had the lowest mean HAZ score (-0.65, SD=1.15). The age category with the highest mean HAZ score was 12 to 14 months (-0.02, SD=1.33).

Table 4.6: HAZ Central tendency and dispersion Z scores by age category (n=400)

Age	n	Mean	SD	Minimum	Q1	Median	Q3	Maximum
0-2	49	-0.33	1.11	-3.39	-1.09	-0.40	0.26	2.54
3-5	79	-0.16	1.67	-4.90	-0.93	-0.19	0.75	4.52
6-8	71	-0.24	1.40	-4.91	-0.99	-0.17	0.66	2.70
9-11	60	-0.24	1.08	-3.55	-0.91	-0.25	0.45	2.49
12-14	50	-0.02	1.33	-4.07	-0.65	-0.12	0.73	3.37
15-17	33	-0.65	1.15	-3.32	-1.51	-0.49	0.14	1.70
18-20	39	-0.19	1.43	-4.13	-0.76	-0.13	0.73	2.40
21-23	19	-0.35	0.92	-2.14	-0.89	-0.47	0.41	1.25

The central tendency and dispersion for male participants HAZ according to the age category is presented in Table 4.7 and females in Table 4.8. The lowest mean HAZ in males was in the 15 to 17 month category (Mean: -0.82; SD=1.30). The highest mean HAZ score was within the 12 to 14 month age category for males (-0.12; SD=1.26). The lowest mean HAZ for female participants was the 15 to 17 month age category. Among the female age categories, the 12 to 14 month age category had the highest mean HAZ (0.07; SD=1.39).

Table 4.7: HAZ central tendency and dispersion Z scores and MUAC for male participants by age category (n=199)

Age	n	Mean	SD	Minimum	Q1	Median	Q3	Maximum
0-2	25	-0.30	1.29	-3.39	-1.14	-0.11	0.11	2.54
3-5	33	-0.21	1.40	-4.90	-0.76	-0.15	0.64	3.25
6-8	40	-0.42	1.48	-4.91	-1.19	-0.30	0.63	2.70
9-11	29	-0.32	1.22	-3.55	-0.84	-0.38	0.23	2.49
12-14	24	-0.12	1.26	-2.24	-0.72	-0.38	0.63	3.37
15-17	20	-0.82	1.30	-3.32	-1.88	-0.73	0.16	1.70
18-20	18	-0.20	1.57	-3.95	-1.18	-0.06	0.72	2.40
21-23	10	-0.60	1.00	-2.14	-1.14	-0.59	0.27	0.69

Table 4.8: HAZ central tendency and dispersion Z scores and MUAC for female participants by age category (n=201)

Age	n	Mean	SD	Minimum	Q1	Median	Q3	Maximum
0-2	24	-0.33	0.83	-1.62	-0.85	-0.43	0.28	1.36
3-5	46	-0.12	1.84	-324	-1.18	-0.19	0.79	4.52
6-8	31	-0.01	1.26	-2.94	-0.70	0.14	0.73	2.51
9-11	31	-0.16	0.92	-1.71	-1.03	-0.10	0.49	1.37
12-14	26	0.07	1.39	-4.07	-0.45	0.34	0.73	2.67
15-17	13	-0.39	0.86	-1.67	-0.94	-0.41	0.14	1.12
18-20	21	-0.17	1.30	-4.13	-0.59	-0.14	0.48	1.68
21-23	9	-0.07	0.78	-0.91	-0.66	-0.29	0.62	1.25

Severe stunting (HAZ<-3) was prevalent among three percent (n=12) of the total participants, while 6% (n=23) of the total sample was moderately stunted (HAZ<-2). Among the males, 4% (n=8) of the participants were severely stunted. Severe stunting was prevalent among 2% (n=4) of the females. Moderate stunting affected 7% (n=14) of the male participants and 5% (n=9) of the female participants The HAZ frequency and distribution is presented in Figure 4.2. There was no significant difference in HAZ between the two genders (p=0,72). Males were at a higher risk for stunting (RR=1.74) than females but this was not significant (p>.05).

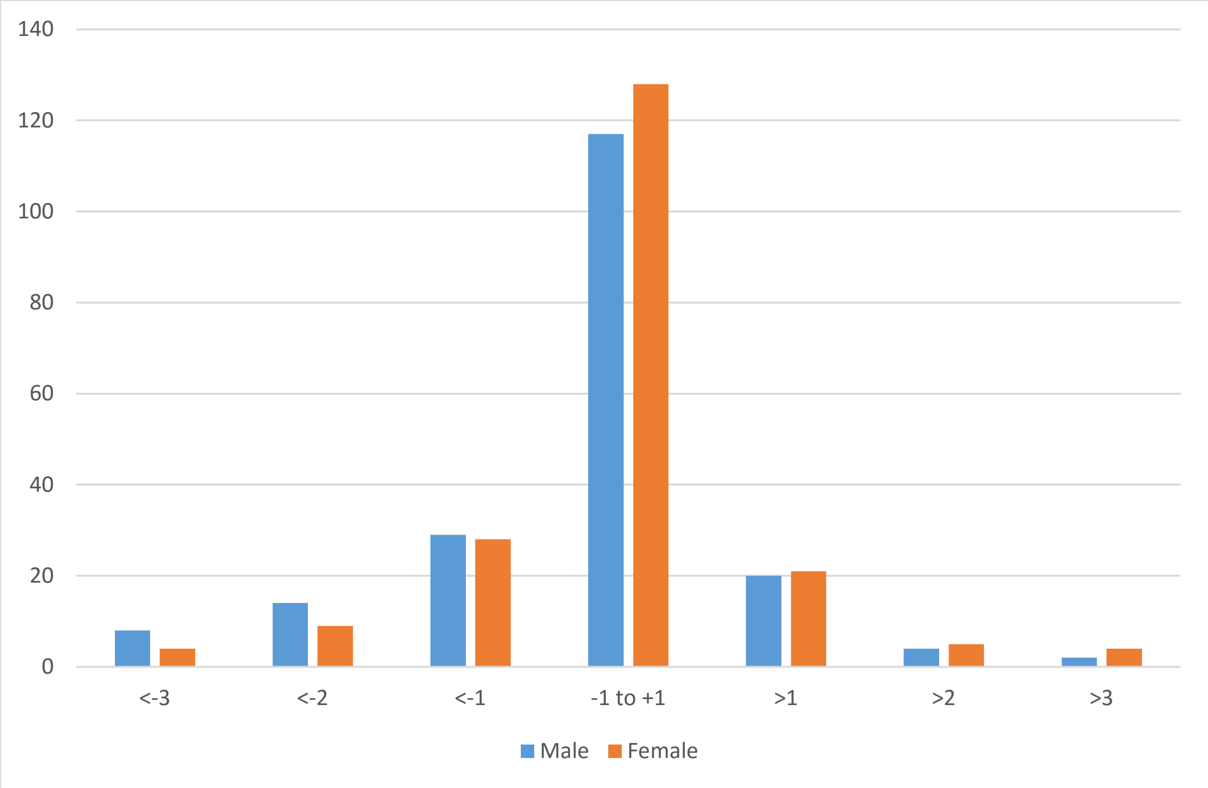

Figure 4.2: Height for age (HAZ) frequency and distribution (n=393)

Despite no significant age differences between the gender groups, male participants were significantly (p<0.05) taller than female participants (Table 4.9). As there was no significance according to the Cohen's d test, this difference is of little practical importance. There was no statistically significant difference (p=0.092) in nutritional status in terms of HAZ between males and females.

Table 4.9: Height measurement central distribution and T-tests by gender category (n=399)

Gender		**n**	**Mean**	**SD**	**Difference**	**p-value**	**Cohen's D**
Height (cm)	Male	197	70,83	8,86	1,78	0,049*	0,20
	Female	200	69,04	9,12			
HAZ	Male	194	-0,36	1,36	-0,23	0,092	0,17
	Female	199	-0,13	1,31			

*Significant to p<.05

4.3.3 Wasting

The mean WHZ was 0,83 (SD=1,28). The central tendency and distribution for WHZ for the sample is presented in Table 4.10. The zero to two month age category had the lowest mean WHZ score (0.41; SD=1.35) and the age category with the highest mean WHZ score (1.19; SD=1.13) was the 18 to 20 month age category. The WHZ score distribution for male participants is illustrated in Table 4.11. Male infants zero to two months had the lowest mean WHZ (0.31; SD=1.70). Male children 12 to 14 months old had the highest WHZ (1.15; SD=0.93).

Table 4.10: WHZ central tendency and dispersion Z scores participants by age category for total sample (n=400)

Age	n	Mean	SD	Minimum	Q1	Median	Q3	Maximum
0-2	49	0.41	1.35	-3.03	-0.28	0.41	1.35	2.90
3-5	79	0.71	1.12	-2.97	0.03	0.74	1.36	4.35
6-8	71	0.81	1.33	-2.61	0.11	0.79	1.28	3.86
9-11	60	0.93	1.36	-1.47	-0.04	0.97	1.82	4.48
12-14	50	1.07	1.10	-1.13	0.38	0.87	1.59	4.31
15-17	33	0.90	1.44	-1.75	-0.32	1.00	2.03	3.78
18-20	39	1.19	1.13	-1.07	0.76	1.31	1.76	4.36
21-23	19	0.68	1.49	-1.26	-0.20	0.33	1.39	4.57

Table 4.11: WHZ central tendency and dispersion Z scores for male participants by age category (n=199)

Age	n	Mean	SD	Minimum	Q1	Median	Q3	Maximum
0-2	25	0.31	1.70	-3.03	-0.81	0.18	1.42	2.90
3-5	33	0.70	1.21	-1.91	0.05	0.40	1.31	4.35
6-8	40	0.57	1.50	-2.61	-0.42	-0.40	1.21	3.86
9-11	29	0.79	1.51	-1.47	-0.35	0.68	1.63	4.48
12-14	24	1.15	0.93	-1.13	0.67	1.00	1.81	3.18
15-17	20	0.83	1.53	-1.75	-0.35	1.00	2.04	3.78
18-20	18	1.29	1.15	-1.07	0.91	1.31	1.73	4.36
21-23	10	0.73	1.24	-0.97	-0.19	0.50	1.39	3.12

The central tendency for WHZ score for female participants is presented in Table 4.12.

Table 4.12: WHZ central tendency and dispersion Z scores and MUAC for female participants by age category (n=201)

Age	n	Mean	SD	Minimum	Q1	Median	Q3	Maximum
0-2	24	0.52	0.86	-1.48	-0.02	0.48	1.10	2.28
3-5	46	0.71	1.07	-2.97	0.07	0.89	1.36	3.21
6-8	31	1.11	1.01	-1.07	0.42	1,06	1.56	3.60
9-11	31	1.03	1.21	-0.99	0.24	0.97	1.2	4.07
12-14	26	0.96	1.24	-0.67	0.24	0.61	1.28	4.31
15-17	13	1.00	1.36	-1.10	-0.29	1.00	2.03	3.32
18-20	21	1.04	1.14	-0.93	0.08	1.10	1.75	3.67
21-23	9	0.63	1.80	-1.26	-1.10	0.33	0.39	4.57

One child in the sample (n=1) was classified as severely wasted, according to WHZ Z-score (WHZ<-3) (Figure 4.3.11). One percent (n=3) of the sample was moderately wasted (WHZ<-2). Six percent of the sample was mildly wasted (WHZ<-1). Eleven percent (n=44) of the children sampled were overweight (WHZ>+2) and five percent (n=21) of the children were obese (WHZ>+3). Male participants were at an elevated risk for wasting compared with female participants (RR=3.0); however, this risk was not significant (p>.05).

As shown in Figure 4.3, the WHZ frequency distribution is skewed to the right. The majority of infants and young children had WHZ scores of greater than -1 SD. Half of the sample (n=200) had WHZ scores of between -1 and +3 SD.

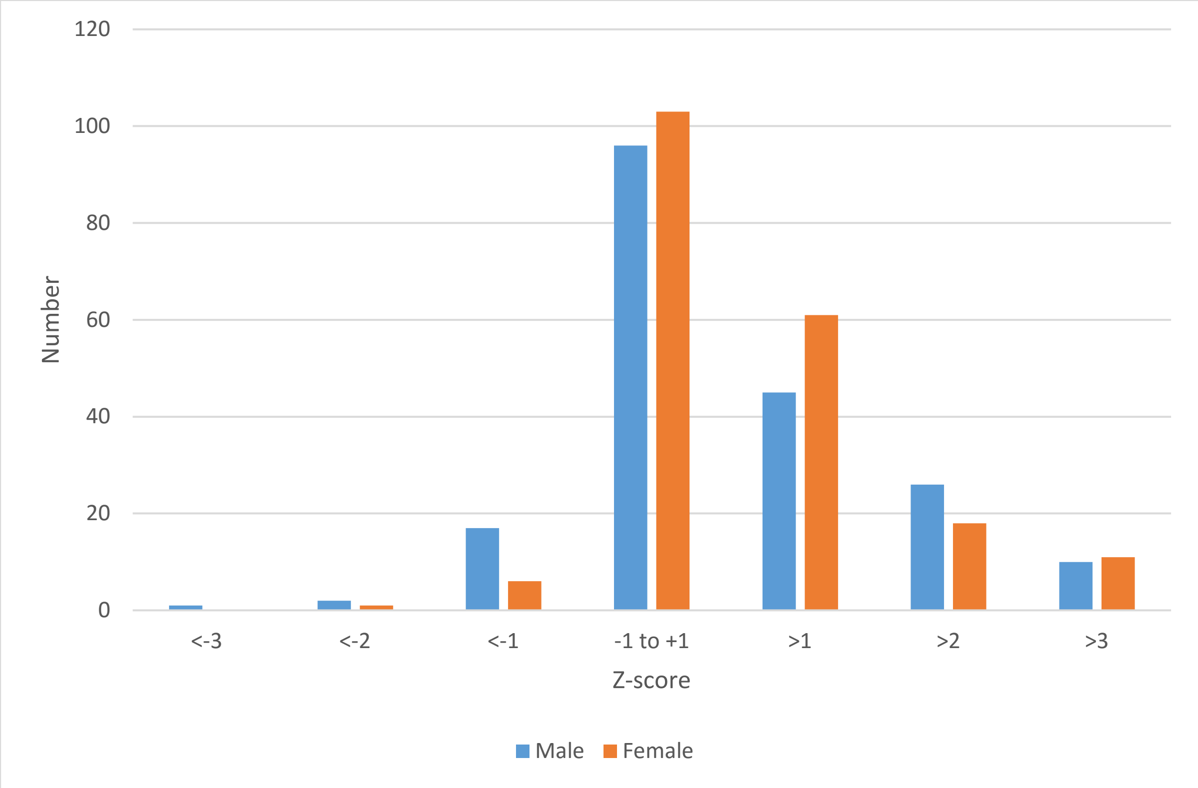

Figure 4.3: Weight for height frequency and distribution (n=397)

As previously indicated, there were statistically significant differences in the weights and heights of male and female participants. However, as shown in Table 4.13, there was no significant difference in the nutritional status in terms of WHZ between the gender categories.

Table 4.13: Differences in anthropometric indicators between male and female participants

	Gender	n	Mean	SD	Difference	p-value	Cohen's D
Weight (kg)	Male	199	9.19	2.59	0.60	0.018*	0.24
	Female	200	8.58	2.49			
Height (cm)	Male	197	70.83	8.86	1.78	0.049*	0.20
	Female	200	69.04	9.12			
WHZ	Male	197	0.77	1.40	-0.12	0.367	0.09
	Female	200	0.88	1.15			

*Significant to p<.05

4.3.4 MUAC screening for wasting

The total sample had a mean MUAC of 15.38 cm (SD=1.75). Mean MUAC measurements range from 13.53cm to 16.41cm across the age categories (Table 4.14), The absolute MUAC measurements varied the most in the youngest (zero to two month month) age category.

Table 4.14: Central tendency MUAC for all participants by age category (n=399)

Age	n	Mean	SD	Minimum	Q1	Median	Q3	Maximum
0-2	49	13.53	1.91	10.90	12.50	13.40	14.00	23.40
3-5	79	14.61	1.38	11.20	13.55	14.70	15.50	18.10
6-8	71	15.38	1.32	12.60	14.20	15.30	16.30	19.00
9-11	59	15.86	1.61	12.60	14.65	15.60	16.80	19.90
12-14	50	16.10	1.29	13.40	15.23	16.20	16.60	19.60
15-17	33	16.30	1.69	13.40	14.90	16.70	17.70	19.00
18-20	39	16.41	1.43	12.40	15.65	16.30	17.35	19.70
21-23	19	16.28	1.48	14.20	15.40	16.20	16.95	19.70

The MUAC central tendency for male participants is presented in Table 4.15. The absolute MUAC mean for males (15.59cm) were statistically significantly different to the absolute MUAC mean value for females (15.17cm) (p=0.017).

Table 4.15: Central tendency MUAC for male participants by age category (n=199)

Age	n	Mean	SD	Minimum	Q1	Median	Q3	Maximum
0-2	25	13.54	1.48	10.90	12.40	13.50	14.20	16.60
3-5	33	14.98	1.51	11.40	14.30	14.90	16.00	18.10
6-8	40	15.44	1.38	12.60	14.35	15.35	16.30	19.00
9-11	29	16.09	1.68	13.10	14.90	15.80	17.40	19.90
12-14	24	16.30	1.28	14.00	15.50	16.20	16.93	19.10
15-17	20	16.51	1.71	13.40	15.05	16.85	17.75	19.00
18-20	18	16.59	1.26	14.70	15.75	16.40	17.40	19.10
21-23	10	16.57	1.28	14.40	16.15	16.65	17.03	19.30

As shown in Table 4.16, the mean female MUAC measurements are slightly lower than their male counterparts per age group. The nine to eleven month age group has the greatest variance in MUAC measurement. As expected, differences in the mean MUAC measurements are only significantly different in females between age categories younger than five months and categories greater than six months (p=0.0005) but not among children older than six months.

Table 4.16: Central tendency MUAC for female participants by age category (n=201)

Age	n	Mean	SD	Minimum	Q1	Median	Q3	Maximum
0-2	24	13.53	2.30	11.20	12.65	13.15	13.60	23.60
3-5	46	14.33	1.22	11.20	13.40	14.60	15.20	16.80
6-8	31	15.32	1.24	13.40	14.20	15.20	16.10	17.80
9-11	31	15.13	3.19	0.00	14.45	15.50	16.35	19.30
12-14	26	15.92	1.30	13.40	15.05	16.20	16.58	19.60
15-17	13	15.99	1.66	13.60	14.40	16.00	17.30	18.30
18-20	21	16.25	1.58	12.40	15.60	16.20	17.30	19.70
21-23	9	15.97	1.69	14.20	14.80	15.80	16.20	19.70

Two percent (n=7) of the sampled children were severely wasted according to mid-upper arm circumference (MUAC<11.5cm). Three percent (n=11) of the children were moderately wasted with a MUAC<12.5cm (Figure 4).

Table 4.17: MUAC and gender category (n=399)

MUAC category	Male n	Male %	Female N	Female %	Total n	Total %
SAM	3	2	4	2	7	2
MAM	6	3	5	3	11	3
Normal	190	95	191	96	381	95
Total	199	100	200	100	399	100

The distribution of MUAC for age Z-scores (MAZ) for the participants is presented in Figure 4.4. The distribution of MAZ scores is skewed to the right. Of the sample, 42% (n=122) had a MAZ between +1 and -1 SD. MAZ was greater than +2 SD among 18% (n=52) of the sample and five percent (n=15) of the sample had MAZ greater than +3 SD.

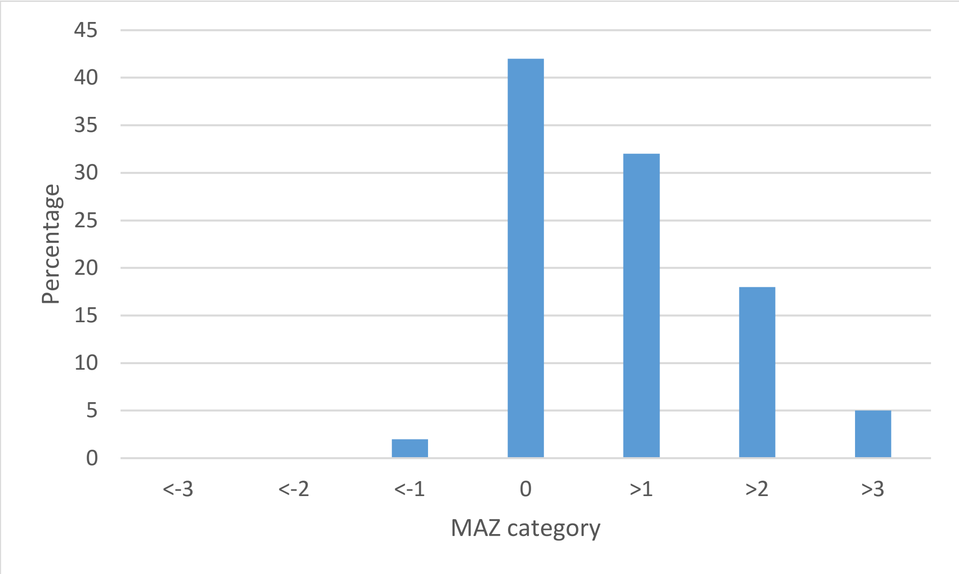

Figure 4.4: Percentage of participants per MAZ category (n=291)

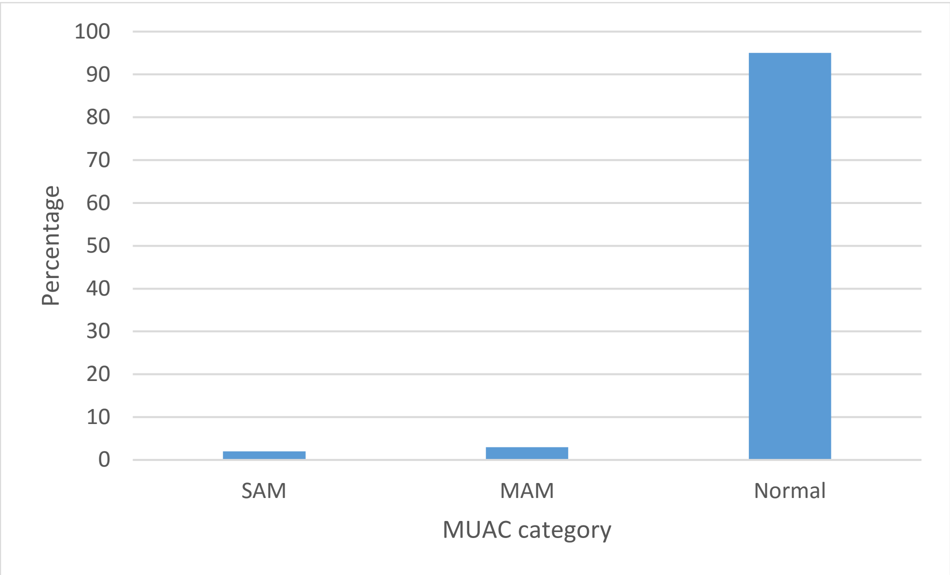

Figure 4.5: Mid-upper arm circumference distribution (n=399)

As expected, absolute MUAC increases with age category. Significant differences are seen between age categories 0-2 months, 3-5 months, and 6-8 months when using a Scheffe test. However, no significant differences are observed between age groups greater than 6 months. P-values for the differences in mean MUAC measurements between age categories are presented in Table 4.18 below. This information confirms and ensures the applicability of a single MUAC recommendation for infants and children older than six months. High mean MUAC values were observed even among the youngest age groups.

Table 4.18: P-values demonstrating the differences in mean absolute MUAC measurements for age categories

Age category		**3 - 5 months**	**6 - 8 months**	**9 - 11 months**	**12 - 14 months**	**15 - 17 months**	**18 - 20 months**	**21 - 23 months**
	MUAC (cm)	**14,65**	**15,38**	**15,86**	**16,04**	**16,30**	**16,43**	**16,28**
0 - 2 months	**13.50**	0.017	<0.0005*	<0.0005*	<0.0005*	<0.0005*	<0.0005*	<0.0005*
3 - 5 months	**14.65**		0.246	0.003*	0.001*	<.0005*	<0.0005*	0.011
6 - 8 months	**15.38**			0.860	0.574	0.283	0.097	0.598
9 - 11 months	**15.86**				1.000	0.964	0.843	0.991
12 - 14 months	**16.04**					0.999	0.984	1.000
15 - 17 months	**16.30**						1.000	1.000
18 - 20 months	**16.43**							1.000

*statistically significant

4.4 THE CORRELATION BETWEEN MUAC AND WHZ IN MOTHERWELL

The sample of children younger than two years from Motherwell showed that the prevalence of wasting was low, and that the sample tended towards being stunted and overweight. Correlations between MUAC and WHZ are investigated in order to develop a community-specific MUAC cut-off value for acute malnutrition.

After removing the infants below six months of age from the sample, the relationship between WHZ and MUAC among male participants between six and 24 months old is presented in Figure 4.6. The correlation coefficient for this relationship is r=0.728 (n=140). This indicates a strong linear relationship between WHZ and MUAC among male participants between six and 24 months old. The coefficient of determination (R^2) is 0.5299, indicating that 52.99% of the variability in MUAC is due to its linear relationship with WHZ.

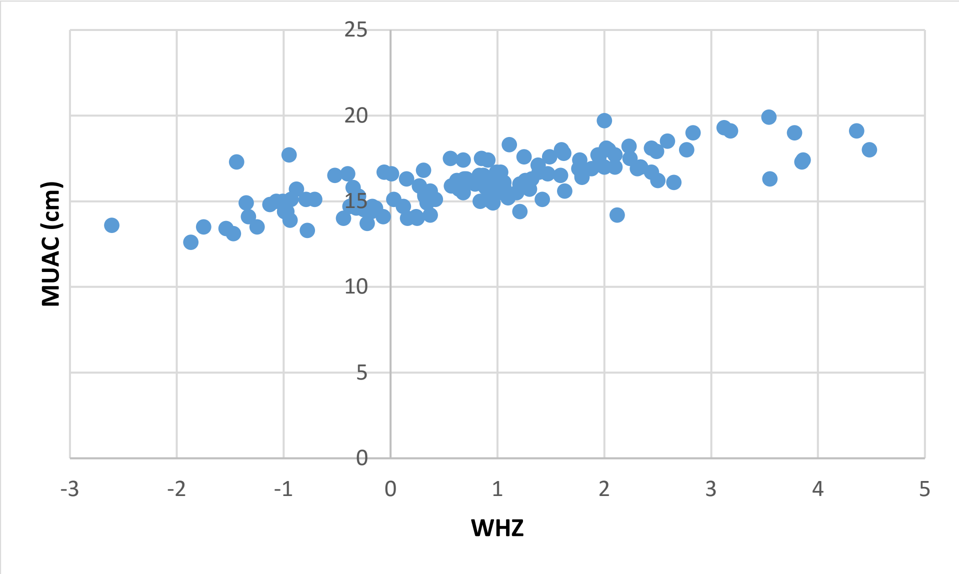

Figure 4.6: The relationship between WHZ and MUAC among male participants, six to 24 months old (n=140)

The relationship between WHZ and MUAC among female participants between six and 24 months old is presented in Figure 4.7. The correlation coefficient for this relationship is r=0.739. This also indicates a strong positive linear relationship between WHZ and absolute MUAC. The coefficient of determination (R^2) is 54.6%, meaning that 54.6% of the variability in MUAC is accounted for by its linear relationship with WHZ.

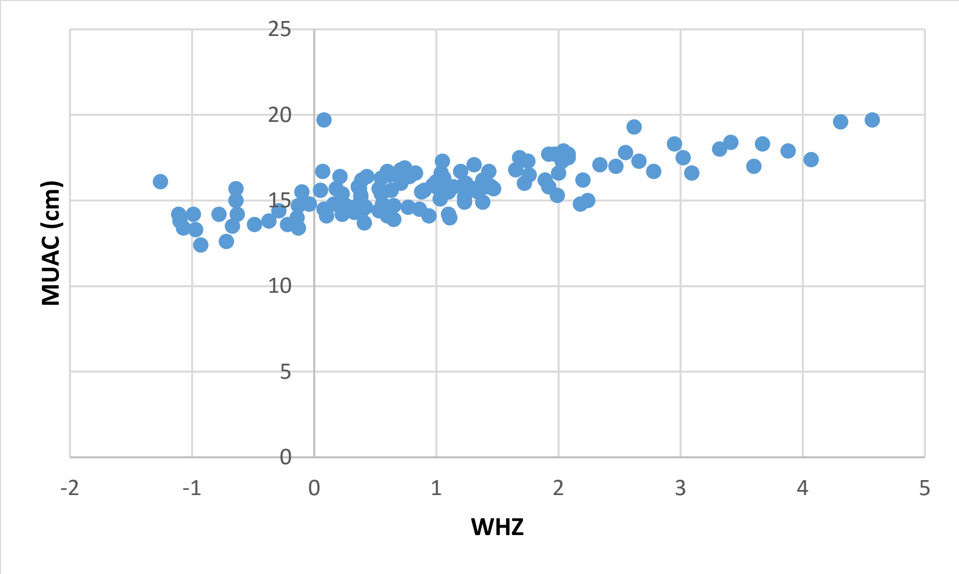

Figure 4.7: The relationship between WHZ and MUAC among female participants between six and 24 months old (n=130)

A strong positive correlation (r=0.67) was found between WHZ and MAZ for children younger than 24 months old. The mean WHZ (n=397) was 0.83 (SD=1.28) and the mean MAZ (n=287) was 1,17 (SD=1.64). The relationship between WHZ and MAZ is presented in Figure 4.8.

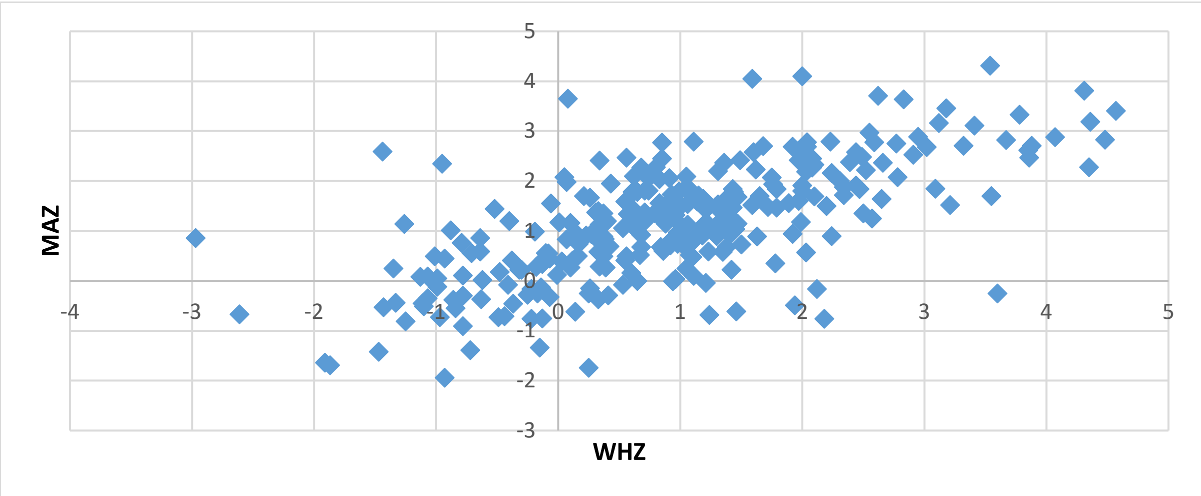

Figure 4.8: The relationship between WHZ and MAZ for male and female participants

4.5 ABSOLUTE MUAC AS A PREDICTOR OF WHZ

A strong positive relationship between WHZ and MUAC has been demonstrated. Building on the relationship between WHZ and MUAC, the ability of MUAC to predict nutritional status is subsequently explored.

Table 4.19 presents the relationship between WHZ and MUAC, per age category for male participants. Least squares regression analyses were conducted for each age group. These equations may be used to predict MUAC values for any given WHZ value. The 21 to 23 month age group has the strongest relationship between WHZ and MUAC, as it has the highest coefficient of determination (R^2=0.787). However, the sample size for this age category is small (n=10). The 12 to 14 month age category has the second highest R^2 value (0.714) and a relatively larger sample size (n=23).

Table 4.19: Relationship between WHZ and MUAC per age category for male participants

Age group	n	r	R^2	Least squares regression formula
0-2	25	.566	.320	Y=13.38+0.491*x*
3-5	33	.590	.348	Y=14.46+0.746*x*
6-8	40	.628	.394	Y=15.10+0.578*x*
9-11	29	.809	.654	Y=15.37+0.9*x*
12-14	**23**	**.845**	**.741**	**Y=14.91+1.07*x***
15-17	20	.79	.626	Y=15.77+0.88*x*
18-20	17	.802	.643	Y=15.41+0.90*x*
21-23	10	.887	.787	Y=15.99+0.79*x*

Table 4.20 presents the relationship between WHZ and MUAC per age category for female participants. This table presents correlation coefficients (r) and coefficients of determination (R^2) as well as least squares regression equations per age group. The age group with the strongest relationship between WHZ and MUAC is the 15 to 17 month age category (r=0.952; R^2=0.906; n=13).

Table 4.20: Relationship between WHZ and MUAC per age category for female participants

Age group	n	r	R^2	Least squares regression formula
0-2	24	.097	Negligible	No correlation
3-5	46	.430	.1849	Y=13.98+0.49*x*
6-8	31	.725	.525	Y=14.33+0.89*x*
9-11	30	.708	.501	Y=14.523+0.14*x*
12-14	26	.790	.624	Y=15.13+0.83*x*
15-17	**13**	**.952**	**.906**	**Y=14.82+1.17*x***
18-20	21	.581	.337	Y=15.41+0.81*x*
21-23	9	.856	.733	Y=15.46+0.80*x*

4.6 DETERMINE SENSITIVITY AND SPECIFICITY OF MUAC AS PREDICTOR OF MALNUTRITION

Sensitivity is a measure of a diagnostic tools ability to identify the presence of a health condition. The specificity of a diagnostic tool refers to the accuracy of correct diagnoses made by the tool. A sensitive and specific tool includes as many “true positives” as possible, while minimising the number of “false negatives” obtained using the tool.

The sensitivity and specificity of the current MUAC cut-off vales for moderate and severe wasting were subsequently tested. The results are presented in Table 4.21. One child was identified as moderately wasted (WHZ<-2), however the child’s MUAC category was >130mm, not identifying wasting, as shown in Table 4.21. One child was classified as moderately wasted using MUAC (MUAC<12.5cm), but was classified as normal according to WHZ (WHZ>-2).

Table 4.21: Diagnosis of acute malnutrition by MUAC and WHZ category (children 6 months and older)

	MUAC				Cumulative			
WHZ category	<11.5cm		<12.5cm		<13.0cm		>13.0cm	
	n	%	n	%	n	%	n	%
<-3	0	0.0%	0	0.0%	0	0.0%	0	0.0%
<-2	0	0.0%	0	0.0%	0	0.0%	1	100.0%
>-2	0	0.0%	1	0.4%	1	0.4%	265	99.6%
Total	0	0.0%	1	0.4%	1	0.4%	266	99.6%

As shown in Table 4.22 below, the current MUAC cut-off recommendation does not identify any of the children in the sample as MAM. Increasing the MUAC cut-off to 13,0cm does not improve the sensitivity or specificity of MUAC for identifying MAM. An even higher MUAC cut-off value was found to have a much increased likelihood of identifying MAM (see Table 4.25 and Table 4.26).

Table 4.22: Diagnostic test results for wasting (WHZ<-2) using MUAC

	12.0cm	**12.5cm**	**13.0cm**
Sensitivity	0.0%	0.0%	0.0%
Specificity	100.0%	99.6%	99.6%

4.7 DEVELOP MALNUTRITION SCREENING CUT-OFF VALUES RELEVANT TO THIS POPULATION

The least squares regression equations presented in Table 4.19 and Table 4.20 were used to construct MUAC cut off value tables corresponding to WHZ categories per age group. The results of testing WHZ are presented in Table 4.21. Table 4.23 below presents the suggested MUAC cut-off values corresponding to WHZ scores for male infants and young children from Motherwell, NMB. Inconsistent increases in MUAC measurements for increasing age categories is possibly due to the insignificant differences in MUAC between them, as stated above (Table 4.18). MUAC values corresponding to WHZ<-2 were greater than 12.5cm for all age categories above zero to two months.

Table 4.23: Suggested age related MUAC cut-off values (cm) for male infants and young children from Motherwell, NMB

Age group	WHZ<-3	WHZ<-2	WHZ<-1	WHZ=0	WHZ>+2
0-2	11.807	12.298	12.789	13.280	14.262
3-5	12.222	12.968	13.714	14.460	15.952
6-8	13.366	13.944	14.522	15.100	16.256
9-11	12.677	13.577	14.477	15.377	17.177
12-14	11.689	12.761	13.833	14.905	17.049
15-17	13.106	13.994	14.882	15.770	17.546
18-20	12.695	13.599	14.503	15.407	17.215
21-23	13.632	14.419	15.206	15.993	17.567

Table 4.24: Suggested age related MUAC cut-off values (cm) for female infants and young children from Motherwell, NMB

Age group	WHZ<-3	WHZ<-2	WHZ<-1	WHZ=0	WHZ>+2
0-2	No correlation	No correlation	No correlation	No correlation	No correlation
3-5	12.505	12.997	13.489	13.981	14.965
6-8	11.673	12.560	13.447	14.334	16.108
9-11	11.481	12.495	13.509	14.523	16.551
12-14	12.633	13.464	14.295	15.126	16.788
15-17	11.320	12.487	13.654	14.821	17.155
18-20	12.994	13.800	14.606	15.412	17.024
21-23	13.059	13.860	14.661	15.462	17.064

A single MUAC cut-off for males aged six to 24 months was developed for WHZ<-2. The r-value for the relationship between WHZ and MUAC for all males older than six months was 0.728. This means that the relationship between WHZ and MUAC is positive and linear. The least squares regression formula was used to predict where WHZ=-2 corresponds with MUAC. The predicted MUAC value was then tested for sensitivity and specificity, and the results are presented in Table 4.25 below. The MUAC cut-off value for males is 13,8cm.

Table 4.25: Single MUAC cut off for MAM and SAM males (WHZ<-2), 6-24 months

N	140
R	0.728
r^2	52.99%
Least squares linear regression equation	Y=15.409+0.803x
MUAC cut off for WHZ<-2	**13.803cm**
Sensitivity	100%
Specificity	94.5%

The single cut-off for females corresponding to WHZ<-2 is presented in Table 4.26 below. The sensitivity could not be calculated due to the sample, but 96.4% specificity was achieved. The suggested MUAC cut-off value is 13.47cm.

Table 4.26: Single MUAC cut off for MAM and SAM females (WHZ<-2), 6-24 months

N	26
R	0.790
r^2	64.2%
Least squares linear regression equation	Y=15.13+0.83x
MUAC cut off for WHZ<-2	**13.47cm**
Sensitivity	Undefined
Specificity	96.4%

4.8 WHAT IS THE ASSOCIATION BETWEEN BIRTHWEIGHT OR FOOD SECURITY AND WASTING AND STUNTING?

4.8.1 Associations between LBW and nutritional status

Of the 388 participants 22 (5.7%) had a LBW. LBW children had a significantly (p<0.0005) lower mean weight-for-age Z-score of -0.64 (SD=1.64) compared with 0.50 (SD=1.21) in normal birth weight (NBW) children. This is presented in Table 4.27. A significantly lower mean height-for-age Z-score (HAZ) was also observed for LBW (-1.81; SD=1.81) children compared to NBW (-0.16; SD=1.24) children. No significant differences were demonstrated between birth weight groups in terms of wasting.

Table 4.27: t-Tests by birth weight category for anthropometric indicators of nutritional status

Variable	Birth Weight Category	n	Mean	SD	Difference	T	d.f.	P	Cohen's d
WAZ	LBW	22	-0.64	1.64	-1.13	-4.17	382	<0.0005	0.91
	Normal	362	0.50	1.21					Large
HAZ	LBW	22	-1.81	1.81	-1.65	-5.90	380	<0.0005	1.30
	Normal	360	-0.16	1.24					Large
WHZ	LBW	22	0.67	1.34	-0.17	-0.59	384	0.555	0.13
	Normal	364	0.84	1.29					Not
MUAC	LBW	22	15.39	1.70	0.02	0.05	386	0.964	0.01
	Normal	366	15.37	1.76					Not

4.8.2 Household food security and the CCHIP Questionnaire

The results of the CCHIP questionnaire, presented in Table 4.28, reveal that 23% of the study sample was food secure (CCHIP score of 0). It was found that 47% of the sample was at risk of hunger (CCHIP score of one to four), while 31% were classified as hungry (CCHIP score of greater than five, Lewit and Kerrebrock 1997).

The mean CCHIP score from the study sample (n=305) was 3.14 (SD=2.64). Thus the mean score was within the category at risk of hunger (Lewit and Kerrebrock 1997).

Table 4.28: Results of the CCHIP questionnaire (n=305)

Hunger classification	N	%
Hungry	94	31
At risk	142	47
Food secure	69	23

The results of the CCHIP questionnaire per question is presented in Table 4.29 below.

Table 4.29: Results of the CCHIP questionnaire by question (n=305)

Variable	No		Yes	
	N	%	N	%
Question 1	122	40	183	60
Question 2	132	43	173	57
Question 3	169	55	136	45
Question 4	165	54	140	46
Question 5	206	68	99	32
Question 6	226	74	79	26
Question 7	201	66	104	34
Question 8	260	85	45	15

The distribution of household food security in Motherwell, NMB, is presented in Figure 4.9.

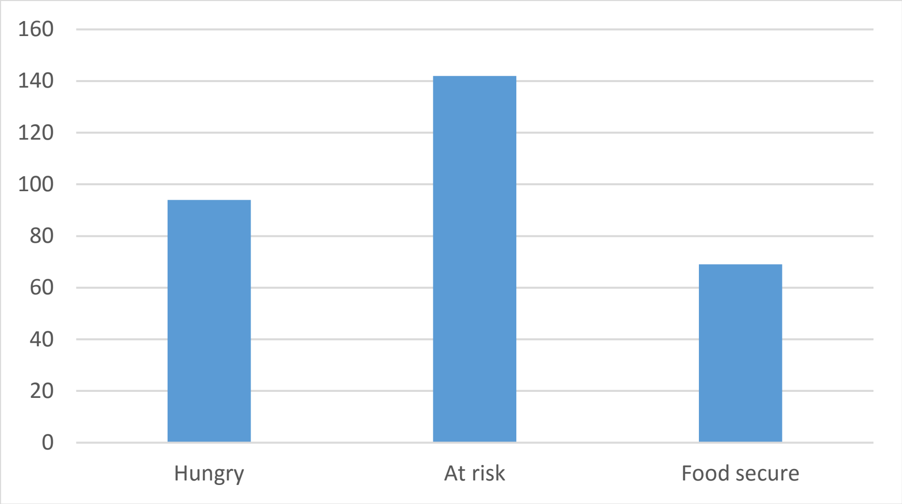

Figure 4.9: Food security distribution in Motherwell, NMB

The central tendencies for WAZ according to HHFS category are presented in Figure 4.10. The median WAZ is the highest among food secure households and decreases with increasing household food insecurity. The mean WAZ was the highest among the children at risk of HHFIS. Children who were at risk of food insecurity had the largest range of WAZ scores.

The central tendencies for HAZ per HHFS category are presented in Figure 4.10. Mean and median HAZ scores were below 0 for all HHFS categories. Hungry children had the lowest median and mean HAZ scores.

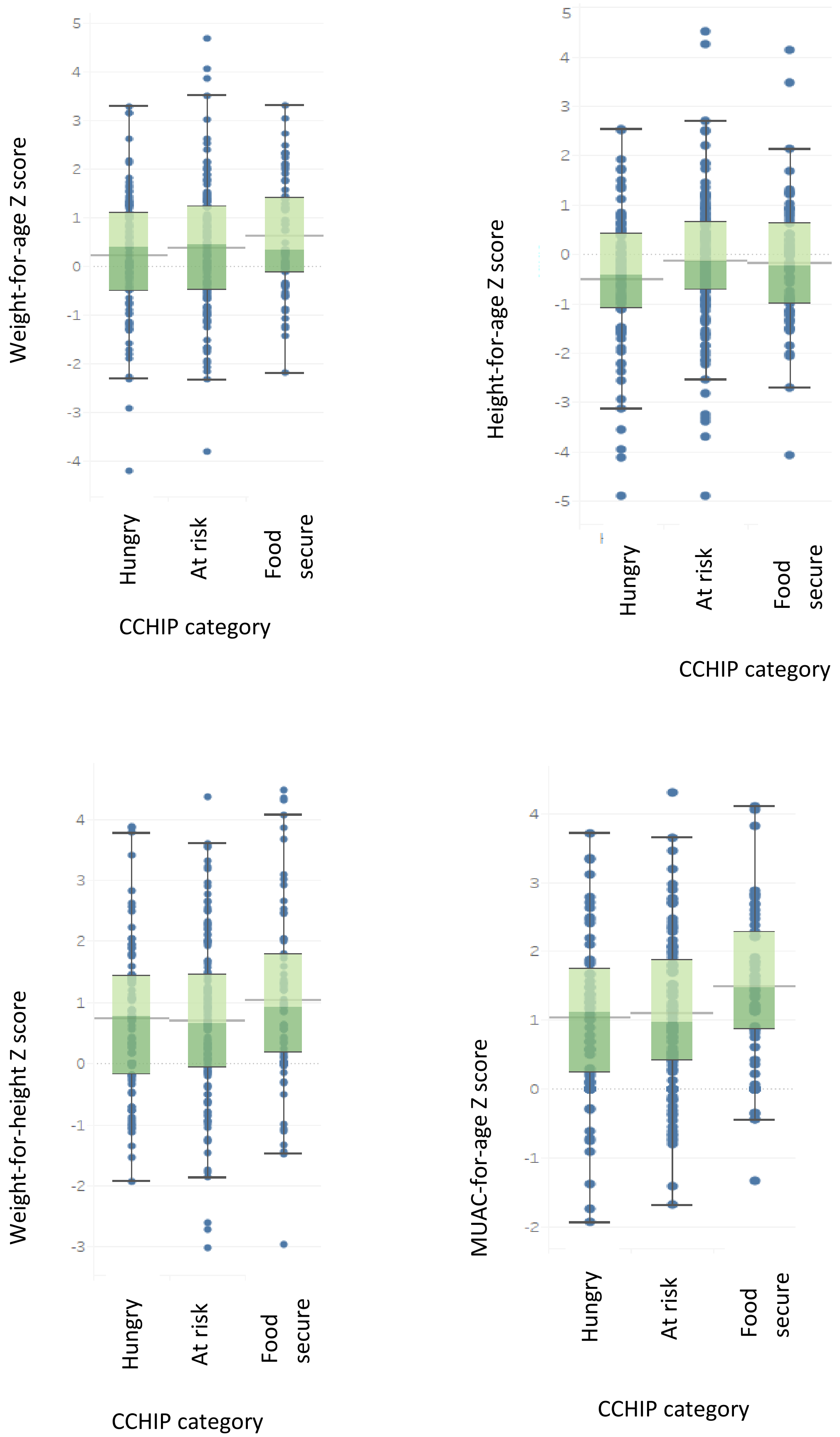

Figure 4.10: Box and whisker plots for anthropometric indicators by CCHIP category

Table 4.30: Mean Z-scores for CCHIP categories

Category	n	WAZ mean (SD)	HAZ	WHZ
Hungry	94	0.233 (1.304)	-0.51 (1.3509)	0.744 (1.2219)
At risk of hunger	142	0.377 (1.309)	-0.137 (1.338)	0.703 (1.3271)
Food secure	69	0.628 (1.169)	-0.192 (1.300)	1.042 (1.4818)

4.9. CONCLUSION

This study aimed to synthesise a profile of the nutritional status of children younger than two years old in Motherwell, NMMM and to assess the value of MUAC as a predictor of malnutrition risk.

The prevalence of underweight among children younger than two years old in Motherwell was 3%. Stunting was prevalent among 9% and wasting among 1%. Although differences in the absolute weights (p=0.018), heights (p=0.049) and MUAC (p<0.017) measurements were observed between male and female participants, mean WAZ, HAZ, WHZ and MAZ were not significantly different between males and females.

There was a strong relationship between MUAC and WHZ (r=0.739). Correlations between MUAC and WHZ were used to develop acute malnutrition MUAC cut-off value recommendations specific to the Motherwell population. Least squares regression analysis was used to project a MUAC cut off value corresponding to WHZ<-2. The MUAC cut-off value suggested to identify MAM (WHZ<-2) is 13.8cm in males and 13.5cm in females in black residents in Motherwell, an urban township in the Eastern Cape.

The sensitivity and specificity of these recommendations were tested to ensure that they are able to identify malnutrition accurately without excluding worthy cases. The 13.8cm cut was shown to have a sensitivity of 100% and specificity of 94.5%. The female MUAC cut-off of 13.5cm had an undefined sensitivity (due to limited sample availability) but had a specificity of 96.4%.

Associations between malnutrition and birth weight were investigated, as well as the effect of HHFS on the nutritional status of children in Motherwell, NMB. LBW was strongly associated with a lower WAZ ($p<0.0005$) than NBW children. Likewise, a significantly lower mean HAZ was also observed for LBW children compared to NBW children.

The results of the CCHIP questionnaire revealed that a large proportion of Motherwell residents are either hungry or at a high risk for hunger. The high prevalence of household food insecurity could be a contributing factor to nutritional problems seen among children younger than two years in Motherwell. These problems include both under- and overnutrition, as expected due to the double burden of disease.

CHAPTER 5

DISCUSSION

Infants and children younger than two years old are a particularly vulnerable group. This is a time when the mortality risk and risk of inhibited growth is highest during childhood (Kattula *et al.,* 2014). Surveys such as this study are useful for health workers to plan effective nutrition interventions, as they provide a baseline for further work and highlight existing areas which require intervention to prevent disease (Halperin and Baker, 1992).

As outlined in the problem setting, WHZ and MUAC as nutritional indicators are both recommended by the WHO for identifying malnourished children at the community level (WHO 2013). According to the WHO, WHZ and MUAC are interchangeable methods for identifying malnutrition. However, researchers have found that WHZ identifies a different set of children as malnourished when tested in comparison to MUAC (Laillou *et al.,* 2014). Although there was not much difference in malnutrition prevalence when using either WHZ or MUAC, Roberfroid *et al.* (2015) found that only one third of children with GAM were malnourished according to both WHZ and MUAC criteria.

The low South African exclusive breastfeeding rate may have resulted in children growing differently to what is expected according to the WHO growth standards, which were based on children who were breastfed. It is thus possible that underprivileged South African children are shorter and with a different body composition due to diluted breastmilk substitutes and mixed feeding practices (Alvarez-Uria *et al*., 2012). The WHZ was twice as sensitive as MUAC in identifying malnutrition among slim children, and the sensitivity of MUAC was also influenced by stunting (Roberfroid *et al* 2015). As mentioned in the problem setting section, the current 12,5cm MUAC cut-off may not be appropriate for use in underprivileged South African children. If 12,5cm is insufficiently sensitive, it may contribute to the discrepancy between the prevalence of malnutrition in the community, and the number of children identified for treatment.

In this chapter, results of the study are discussed in relation to the available literature. This chapter presents the prevalence of malnutrition in Motherwell, NMB, in terms of underweight, stunting, wasting and overweight. Similarities and differences between the results from this study and other studies are discussed. The relationship between

MUAC and WHZ presented in Chapter 4 was used to develop a screening tool for malnutrition specific to this Motherwell population. The usefulness and applicability of this screening tool is argued in this chapter. Low birth weight and HHFIS are underlying factors which contribute to malnutrition. The impact of these factors were illustrated in Chapter 4, and are discussed in the wider context of the nutrition transition in developing regions in this chapter. Finally, recommendations are formulated to develop guidelines for screening of children younger than 24 months in the Eastern Cape.

5.1 WHAT IS THE PREVAENCE OF STUNTING, WASTING AND OVERWEIGHT IN CHILDREN UNDER TWO YEARS OF AGE IN MOTHERWELL?

5.1.1 Underweight

Overall, the WAZ score distribution of the sample was negatively skewed. The majority of the children's WAZ scores fell between the +1 and -1 Z-scores in comparison with the WHO standard. However, there were more children who were overweight for age compared with those who were underweight for age, highlighting the nutrition transition and the double burden of disease also seen in other provinces in South Africa (Mamabolo et al., 2005).

The prevalence of underweight among children younger than two years old in Motherwell was three percent. One percent of the study participants were severely underweight for age (WAZ<-3). Two percent of the children included in the study were underweight for age (-3<WAZ<-2). As the underweight may be due to stunting, rather than wasting as previously pointed out by research by Steenkamp *et al.* (2016) in three other provinces, a similar situation may be developing in the Eastern Cape.

A recent South African study found that underweight, which may include both stunting and wasting, affected only seven percent of children (Christian *et al.,* 2013). Although this sample in Motherwell had a higher mean WAZ score, a lower proportion of underweight children were identified. It could be that that the prevalence of underweight was influenced by the recruitment sites of the study. Infants and children seen at health facilities could potentially be growing better than children who do not attend clinics regularly.

5.1.2 Stunting

The HAZ distribution for the sample was positively skewed. While the majority of children had HAZ scores between the +1 and -1 Z-scores according the WHO standard, there were more children who were stunted for their age than tall.

Stunting affected almost 10 percent of the children participating in this study. Six percent of the total sample was moderately stunted and three percent of the participants were severely stunted. This prevalence is far lower than expected according to other studies conducted in South Africa. Schoeman *et al.* (2010) found that 13% of infants under eleven months old (n=332) were stunted, and 25% of young children between 12 and 23 months old were stunted. According to Shisana *et al*., (2013), 22% of children in the Eastern Cape are stunted with a further four percent severely stunted. The prevalence of stunting in Motherwell is far lower than expected according to the findings of SANHANES-1. It is possible that the low stunting prevalence is due to the urban setting of the population sampled, and because the sample was obtained in part from health facilities.

Among males, four percent of the participants were severely stunted and seven percent were moderately stunted. Severe stunting was prevalent among two percent of females while five percent of female participants were moderately stunted. Similar tendencies were shown by Shisana *et al*. (2013) who reported that 26,9% of male children and 25,9% of female children younger than three years were stunted in South Africa. Kieno *et al.,* (2014) found that males were more vulnerable to stunting than females. Although male participants were significantly taller than females, there was no significant difference in the HAZ scores between males and females. It was also found that males were not at a significantly higher risk for stunting than females. Thus it appears that male children are not at a higher risk of stunting in this population. The conceptual framework on stunting lists household food competition and the child's place in the household resource hierarchy as reasons for children being at risk of stunting (Stewart, Iannotti, Dewey, Michaelsen and Onyango, 2013). Kieno *et al*. (2014) also mention that male children are more likely to attend school, which could influence their nutritional status through school feeding schemes and place them at an advantage over girls in terms of household resource allocation. However, the infants and young children participating in this study were below school-going age and therefore this effect is not yet present. This could mean that boys and girls of this age group are still at a similar risk for malnutrition. Olofin *et al.* (2013) showed that severe stunting is associated with a similar mortality risk as moderate wasting.

Keino *et al.* (2014) reported that people living in rural areas are more vulnerable to stunting. This urban sample also had a lower prevalence of stunting than samples obtained from rural districts in the Eastern Cape and KwaZulu-Natal where stunting was prevalent among almost half of the children (Mamabolo *et al.,* 2005).

The conceptual framework on stunting (WHO, 2013) includes poor micronutrient quality, low dietary diversity and intake of animal foods, the anti-nutrient content of the diet and low energy content of complementary foods as causes of stunting. Energy dense foods are more available in urban communities, and are discussed in further detail in relation to overweight and obesity. It is plausible that the higher availability of high energy foods in urban environments contributes to overweight and obesity while simultaneously protecting against stunting.

Strategies aimed at preventing stunting include universal salt iodization, multiple micronutrient supplementation, community-based intervention strategies for improving breastfeeding and complementary feeding strategies, community based management of severe acute malnutrition and the provision of appropriate complementary foods (Hoddinott *et al*., 2013). However, although these strategies are more accessible to urban populations as part of primary health care services, it did not protect them all against stunting.

5.1.3 Wasting

An earlier study by Mamabolo *et al*. (2005) found that wasting was prevalent among one percent of infants and children younger than three years. The results obtained from Motherwell for infants and children younger than two years appear consistent with these findings. Although the prevalence of wasting in South Africa is low, the incidence of SAM is increasing yearly, affecting approximately 24 000 children in 2014 (Massyn *et al.,* 2014) and therefore remains a public health concern.

The WHZ score distribution of the study participants is negatively skewed. The majority of participants had WHZ scores between +1 and -1 according to the WHO standard. A minority of participants had low WHZ scores.

One child in the sample was classified as severely wasted, according to WHZ Z-score (WHZ<-3). One percent of the sample was moderately wasted (WHZ<-2). Previous studies conducted in South Africa have reported a low prevalence of wasting. According to Shisana *et al*. (2013), less than two percent of Eastern Cape children are moderately wasted while less than one percent is severely wasted. In this sample, the researcher would thus have expected one percent of the sample be severely wasted and two percent to be moderately wasted.

The majority of participants had MAZ scores of between -1 and +1 SD. The majority of the study participants were also classified as normal according to their absolute MUAC measurements. As expected, significant differences in absolute MUAC values were observed between infants younger than six months and children who were older than six months. The current WHO recommendation has a single MUAC cut-off for all children between six and 59 months. According to the Motherwell results in this study, a single cut-off value for children between six months and 24 months is appropriate as MUAC is not significantly different for this age group. Furthermore, it was found that the mean absolute MUAC values for males was significantly different to females, warranting separate MUAC cut-off values for males and females.

5.1.4 Overweight

Eleven percent of the children sampled were overweight (WHZ>+2) and five percent of the children were obese (WHZ>+3). Overweight and obesity appears to be a greater problem among children in Motherwell than wasting. The global prevalence of childhood obesity is increasing. According to De Onis, Blossner and Borghi (2010), the worldwide prevalence of overweight and obesity has been increasing from between 1990 and 2010. The prevalence of overweight in Motherwell is higher than the global average; however, it is similar to the prevalence reported by Schoeman *et al.* (2010), where eleven percent of infants younger than eleven months old were overweight and obese and five percent of those aged twelve to 23 months were overweight and obese in South Africa.

The change in eating behaviours and physical activity levels is driving the increasing prevalence of overweight and obesity in developing regions (Ramachandran, 2011). Igumbor *et al*. (2012) identified rapid urbanisation as a significant factor contributing to the nutrition transition in South Africa. Fat intake has increased faster in urban South

African communities than in rural communities (Goedecke, Jennings and Lambert, 2005), as energy dense processed and prepared foods high in fat and salt rapidly become more accessible in urban environments (Igumbor *et al.,* 2012). Thus, urban communities such as Motherwell are at a high risk for overweight and obesity.

This trend is particularly concerning as overweight and obesity during infancy has been associated with an increased risk of non-communicable diseases later. Barker (2004) reported that infants who are overweight at twelve months have a four-fold increased risk of developing type 2 diabetes in adulthood as well as twice the risk of premature death from CVD when compared with normal weight children.

In a systematic review on the effectiveness of interventions into childhood overweight, none of the interventions reviewed had any effect on preventing childhood overweight and obesity (Monasta, Batty, Macaluso, Ronfani, Lutye, Bavcar, van Lenthe, Brug and Cattaneo, 2011).

The results show that overall, infants and young children from Motherwell are slightly shorter and more overweight than the WHO standard. This pattern may in part explain why MUAC identifies so few children as SAM. It is possible that these children are not being identified as acutely malnourished using current cut off guidelines.

5.2 THE CORRELATION BETWEEN MUAC AND WHZ

Results from this study showed that there is, as expected, a relationship between MUAC and WHZ. Although differences in the absolute weights, heights and MUAC measurements were observed between male and female participants, the mean WAZ, HAZ, WHZ and MAZ were not significantly different between males and females. Therefore, if an absolute MUAC cut-off were to be suggested, separate MUAC cut-off values should be developed for males and females as their MUAC measurements differed significantly. Likewise, significant differences in absolute MUAC have been observed between age groups above and below six months old. This suggests that a single MUAC cut-off for each gender for children older than six months is feasible for this population, which may make it easier for community health and outreach workers to screen for malnutrition.

Joseph *et al*. (2002) raised a concern that current MUAC cut-off values of 12,5cm for MAM and 11,5cm for SAM delay inclusion of children into malnutrition interventions until they are extremely malnourished. Infants and children older than six months had WHZ<-2, but MUAC>12.5cm, therefore their wasting could be advanced before it is identified using MUAC alone as a screening tool.

5.3 IN THE CASE THAT A CORRELATION EXISTS, CAN MUAC PREDICT WHZ?

The results showed a strong positive linear relationship between MUAC and WHZ however, the value of this relationship in making predictions is not good because of the low co-efficient of determination value. A strong positive correlation exists between WHZ and MAZ. The MAZ in this study was a better predictor of malnutrition and results are comparable to WHZ.

If MUAC is to become an effective screening tool for community nutrition use, it should not identify fewer children as malnourished than WHZ (Dasgupta, Sinha, Jain and Prasad, 2013). The development of community-specific adapted MUAC cut-off values for treating malnutrition have already been suggested by Goosens *et al.* (2012). The WHO has suggested that refining MUAC cut-off criteria will improve active community and health facility-based screening for malnutrition, effectively enhancing treatment coverage (WHO, 2013). Raising the MUAC cut-off may increase the number of children included in nutrition interventions, particularly those who are at the highest risk of nutritional deterioration (Ali *et al.,* 2013). Raising the recommended MUAC cut-off value for identifying SAM from 11.5cm to 13.3cm as suggested by Laillou *et al.* (2014), or even as high as 15.5cm, recommended by Dairo, Fatokun and Kuti (2012), results in a higher sensitivity of the tool. However, the raised sensitivity results in a lower specificity, which is problematic because limited funds are available to include children in targeted supplementation programmes. Of more concern is the developing of overweight; therefore supplementation of children who are not malnourished may lead to overweight.

The WHO and UNICEF (2009) recommend that WHZ and MUAC can be used interchangeably as they reveal similar prevalence of SAM in the field. However, Ali *et al.* (2013) found that there is little overlap between the groups of children identified as malnourished using MUAC and WHZ. When the sensitivity and specificity of MUAC was tested, it was found that the current MUAC recommendations did not identify the same children as being acutely malnourished as WHZ. The children whose WHZ fell below -2 SD (thus acutely malnourished) all had MUAC greater than 12.5cm, and were missed by the current MUAC cut offs. Only when the MUAC value was raised to 13.0cm, were children with WHZ<-2 identified.

The existence of the relationship between WHZ and MUAC, and the ability to predict these values based on this relationship, led to the development of MUAC cut-off values for males and females according to this study's outcomes. It has already been established that different cut-off values are necessary for males and females, but not for differences in age categories greater than six months. Using the least squares regression equation, a MUAC cut off value of 13,80cm for males between six and 24 months old was projected. This value has a 100% sensitivity and 94,5% specificity. Therefore, this value was able to identify all of the children with WHZ<-2, while yielding an acceptably low number of false positives for wasting. The value developed for females was 13,47cm, and, although the sensitivity was not calculable, this MUAC cut-off had a specificity of 96,4%.

This adapted MUAC cut-off value for identifying malnourished children satisfies the need for the development of a community-specific adapted MUAC cut-off as suggested by Goosens *et al.* (2012) and the WHO (2013). This recommendation is a higher cut-off than the current MUAC guidelines, and as a result, is likely to include more children into nutrition interventions (Ali *et al.,* 2013).

5.4 WHAT IS THE ASSOCIATION BETWEEN BIRTWEIGHT OR FOOD SECURITY AND WASTING AND STUNTING?

The first 1000 days of life includes the gestational period as well as the transition from breastfeeding to complementary foods. Factors which influence a child's growth begins in utero, and later, the availability of food can influence growth.

5.4.1 The association between birthweight and nutritional status

Approximately six percent of the children sampled had low birth weights. Low birth weight (LBW) occurs in ten percent of South African children (Christian *et al*., 2013). Low birth weight and premature births were significantly associated with stunting, wasting and underweight in sub-Saharan countries and other low- and middle-income countries (Christian *et al.,* 2013). A study by Prendergast *et al.* (2014) suggests that stunting begins in utero, and is associated with chronic inflammation.

In this study, LBW children had a significantly lower mean WAZ compared with normal birth weight (NBW) children. A significantly lower mean HAZ was also observed for LBW children compared to NBW children. No significant differences were demonstrated between groups in terms of wasting. A low birth weight is thus associated with an increased risk of stunting but not wasting in children. Prevention of low birth weight infants is therefore necessary in addressing malnutrition and strategies for its reduction should include maternal health as a priority. Maternal age, stature, physical health and psychosocial health are all factors that contribute to stunting, according to the conceptual framework on stunting (Stewart, Iannotti, Dewey, Michaelsen and Onyango, 2013*).*

Inadequate care for mothers and children, insufficient health services and an unhealthy environment are all underlying causes for childhood malnutrition according to the UNICEF conceptual framework (UNICEF, 1997). Low birth weight results from a short gestation period or intrauterine growth restriction (IUGR) (Kramer, 1987). Sumarmi (2016) reported that maternal height correlates with infant birth length, and that women with a short stature (>145cm) were more likely to give birth to low birth length babies. This is indicative of the intergenerational stunting cycle which links unresolved stunting with intrauterine growth retardation (IUGR).

Strategies to break this stunting cycle include efforts to correct stunting in children. Stunting is associated with IUGR, nutritional intake that does not meet the requirements for rapidly growing young children and frequent infections during early childhood (Bhutta, Ahmed, Black and Cousens, 2008). Strategies to prevent teenage pregnancy will help in reducing stunting, as teenage pregnancy is associated with low birth weight (Surmami, 2016). Teenage pregnancy has reduced from 106 per 1000 women in 1987-1990 to 52 per 1000 in 2006-2009 (Makiwane, 2010).

5.4.2 Associations between food security and nutritional status

Insufficient access to food is one of the underlying causes of malnutrition according to the UNICEF conceptual framework (UNICEF, 1997). Informal urban settings such as Motherwell have the highest prevalence of food insecurity in South Africa (Shisana *et* *al*., 2013). It was estimated in the SANHANES-1 study that one third of people living in these settings were food insecure with a further one quarter of urban informal residents at risk for food insecurity (Shisana *et al*., 2013). The prevalence of food insecurity in Motherwell was similar to the SANHANES-1 findings, as 31% of respondents were hungry. There was a higher percentage at risk of hunger, while less than one quarter of participants were food secure. The SANHANES-1 study showed that almost half of South Africans are food secure (Shisana *et al.,* 2013). Household food security is a problem in Motherwell, and insufficient access to food is an underlying cause of malnutrition (UNICEF, 1997).

Food insecurity has been shown to have a significant association with wasting in children (Motbainor, Worku and Kumie, 2015). The largest proportion of wasted children in Motherwell were among those suffering from hunger or at risk of hunger.

Apart from food insecurity, childhood underweight has also been associated with the total number of meals eaten per day (Motbainor, Worku and Kumie, 2015). A third of the mothers interviewed with the CCHIP questionnaire reported cutting the size of their children's meals or skipping them altogether. Fifteen percent of the women interviewed revealed that their children sometimes go to bed hungry because there is not enough money for a meal.

5.5 RECOMMENDATIONS

The following recommendations were developed based on the outcomes of this study.

5.5.1 Recommendations for dieticians and other health workers

Although the WHO recommends MUAC as an independent criterion for identifying acute malnutrition, some children may be missed by MUAC. Therefore, it is important that WHZ is also calculated regularly where possible as part of routine growth surveillance and surveying.

Current MUAC cut-off values of 11.5cm for SAM and 12.5cm for MAM may not be sensitive enough to detect acute malnutrition in Motherwell. Using 13.8cm as the MAM cut-off for males and 13.5cm for females between six and 24 months of age is more sensitive and specific and will include more children who are acutely malnourished into nutrition programmes before nutritional deterioration results in hospitalisation. The new guidelines developed as a result of this research need to be tested in the community.

As low birth weight is strongly associated with poor growth, especially stunting, in early childhood, LBW could be used as an entry criterion for inclusion in nutrition interventions such as blanket supplementation programmes to impact stunting.

5.5.2 Recommendations for further research

More research is required on the nutritional status of infants and children younger than two years in the Eastern Cape. The effects of the nutrition transition and breastmilk replacement and mixed feeding on growth trajectory and nutritional trends needs to be explored. The effects of the nutritional transition have been documented in studies from developing regions such as India and Mexico as well as South Africa. However, nutritional patterns and behaviours specific to South Africa and the Eastern Cape, such as the low breastfeeding rate, could be contributing to the nutrition transition that is unique to the region. The high prevalence of overweight and obesity and low prevalence of undernutrition seen in Motherwell should be investigated in rural Eastern Cape communities and other regions of the Eastern Cape. Investigations into the nutritional status of children younger than two years in other parts of the Eastern Cape could potentially show whether the high mean WAZ and low mean HAZ observed in Motherwell is an Eastern Cape phenomenon.

The results of the the adjusted MUAC cut-off values suggested should be verified using a sample drawn exclusively from the wider Motherwell community (as opposed to health facilities).

5.6. LIMITATIONS

Cross sectional studies are not the study design of choice to determine growth patterns in children. The low numbers of wasted and stunted children also made it problematic to determine sensitivity and specificity of MUAC in children. Measuring infants and young children in clinics and crèches inherently excludes children who do not attend clinics and crèches and thus the results cannot be generalised.

Other researchers should test the growth trajectories of infants and young children in Motherwell using a longitudinal design. Low birth weight infants were shown to have different body compositions to normal birth weight infants, possibly affecting the accuracy of the results. Targeting malnourished children in in-patient malnutrition facilities could aid in clarifying the relationship between WHZ and MUAC and strengthening the acceptance or rejection of an adapted MUAC cut-off value. Recruiting a homogenously community-based sample from crèches, growth monitoring sites and residences would improve the generalisation of the results.

The number of children with SAM was too low to develop and test a MUAC cut-off value for SAM. The same least squares regression line could be used to determine a MUAC cut off for WHZ<-3, but the sample was inadequate to test the sensitivity and specificity of such a value. The recommended cut-off values include both MAM and SAM cases from the sample.

5.7 CONCLUSIONS

This study was conducted on the nutritional status of infants and young children younger than two years, living in Motherwell, NMB. The sample was obtained from clinics and crèches in the Motherwell area. The study provides baseline data on the wasting and stunting prevalence in children below two years of age in Motherwell, NMBM. This study enabled the development of malnutrition risk screening recommendations uniquely relevant to the community of Motherwell. This recommendation will aid health workers in their assessments, improving the accuracy of measurements.

Overall, the nutritional status of infants and young children residing in Motherwell was good. The majority of them had WAZ, HAZ and WHZ scores within the normal classification range. According to existing screening tools, the prevalence of underweight for age, stunting and wasting were low in this community. Despite this low prevalence however, malnutrition is still present in this population.

The mean WAZ, HAZ and WHZ scores were not different between male and female children. Absolute weight, height and MUAC did, however, differ significantly. The MUAC was also significantly different between children older than six months and younger than six months.

Correlations were found between MUAC and WHZ. The strong positive correlation between MUAC and WHZ appears to support the WHO recommendation that MUAC may be used as an indicator of a wasting status in children. However, current MUAC cut-off values as recommended by the WHO (2006) were shown to have a low sensitivity and specificity for identifying wasted children in Motherwell. Therefore, conducting routine growth monitoring and promotion activities in Motherwell are potentially missing acutely malnourished children if they rely solely on MUAC as the screening method.

The correlation between MUAC and WHZ allowed for the development of community-specific MUAC cut-off values for Motherwell. As absolute MUAC was different between males and females, and because the MUAC of children over six months old was not significantly different, MUAC cut-off values for males and females over the age of six months were developed. A MUAC cut-off value of 13.8cm for males, and a MUAC cut-off value of 13.5cm for females had a high sensitivity and specificity for identifying wasting. Adopting these MUAC cut-off values in Motherwell may increase the number of children included in nutritional interventions as well as include them earlier in the disease progression. The information generated by this study will be valuable to health workers and people who plan nutrition interventions. The study may be used as the basis for future nutrition and health research conducted in the municipality.

It was found that birth weight had a significant association with the nutritional status during the first two years of life. Children who were born with a low birth weight had lower WAZ and HAZ scores than normal birth weight children. However, this effect was not seen in WHZ scores.

Motherwell has a high prevalence of hunger, and many residents are at risk of household food insecurity. This phenomenon may have led to the high rate of child overweight and obesity, an effect associated with the nutritional double burden, and even though the malnutrition rates are lower than expected for an underprivileged urban population, the possibility of micronutrient deficiencies may exist but were not investigated in this study. Existing MUAC values may not be applicable to all communities in South Africa, which may lead to underreporting of children who are at risk of acute malnutrition.

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Addendum A: Data collection sheet

Subdistrict: Site: Fieldworker: Date of visit:

Participant Number	Ethnicity 1 African 2 Coloured 3 White 4 Other	Gender 1 Male 2 Female	Breastfeeding at 18 weeks	Date of Birth	Birth Weight	Age (months)	Weight (kg)	Length (cm)	MUAC (cm)	Number of Live Siblings	Total Number of Siblings	RVD Status 1 Positive 2 Negative 3 Unknown	TB Status 1 Currently on Tx 2 Previously on Tx 3 Never on Tx	Medical History 1 Growth faltering 2 Genetic abnormality 3 None	Child Support Grant (yes/no)	CCHIP* (y/n)							
																1	2	3	4	5	6	7	8

*CCHIP Questions:

1. Does your household ever run out of money to buy food?
2. Do you ever rely on a limited number of foods to feed your children because you are running out of money to buy food for a meal?
3. Do you ever cut the size of meals or skip meals because there is not enough money for food?

1. Do you ever eat less than you should because there is not enough money for food?
2. Do your children ever eat less than you feel they should because there is not enough money?
3. Do your children ever say they are hungry because there is not enough food in the house?
4. Do you ever cut the size of your children's meals or do they ever skip meals because there is not enough money to buy food?
5. Do any of your children ever go to bed because there is not enough money to buy food?

Addendum B: National Health Research Database registration

The National Health Research Database

Log in Register Help & Support

Home Submit New Proposal Researcher Resources Search About

RESEARCH PROPOSAL DETAILS: EC_2015RP34_978

APPLICATION DETAILS

Title of Research Project

ANTHROPOMETRIC INDICATORS IN IDENTIFYING MALNUTRITION RISK AMONG CHILDREN YOUNGER THAN TWO YEARS IN MOTHERWELL, NELSON MANDELA METROPOLITAN MUNICIPALITY

Status of Project

On-Going

Application State

Approved

Propsal Submission Date

2015/07/22

Research Staff assigned to Project/Proposal

Title	Name	Surname	Role	Institution

Aim and Objectives

This study aims to synthesise a profile of actual growth among children younger than two years old in Motherwell, Nelson Mandela Metropolitan Municipality (NMMM) to determine associations between anthropometric indicators for possible use as predictors for malnutrition risk.

Study Area(s)/Field(s)

Description
Child Health

Study Design(s)

Description
Cross-Sectional Study

Data Collection Method(s)

Method Category	Method Description
QUALITATIVE	Direct Observations
QUANTITATIVE	Questionnaire

Sample

A sample will be drawn from the community of Motherwell in the Eastern Cape using a cluster sampling method. A minimum of 30 study participants will be required per cluster, as suggested by the Unit of Statistical Consultation (NMMU).

Data Analysis Tool(s)

Tool Description
Statistician (If Available)
Microsoft Excel

Locations(s) where study will be conducted

Facility

---- Motherwell CHC

Anticipated Start Date

2015/08/31

Anticipated Completion Date

2016/12/31

Institution(s) which gave ethical approval

Institution

NMMU - REC-Department Of Research Capacity Development Nelson Mandela Metropolitan University

Ethics Approval Number

H15-HEA-DIET-002

Date of Ethical Approval

2015/07/21

Date Ethical Approval Expires

2018/07/21

If Clinical Trial, MCC Approved

No

National Clinical Trials Registry Number

Funding source

NMMU Dietetics department research fund, researcher funded

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Addendum C: Research Ethics Committee approval letter

Nelson Mandela Metropolitan University

for tomorrow

• PO Box 77000 • Nelson Mandela Metropolitan University
• Port Elizabeth • 6031 • South Africa • www.nmmu.ac.za

Chairperson: Research Ethics Committee (Human)
Tel: +27 (0)41 504-2235

Ref: [H15-HEA-DIET-002 /Approval]

Contact person: Mrs U Spies

21 July 2015

Dr L Steenkamp
Faculty: Health Sciences
Department: Dietetics
M & P Building, Room 01-15
South Campus

Dear Dr Steenkamp

ANTHROPOMETRIC INDICATORS IN IDENTIFYING MALNUTRITION RISK AMONG CHILDREN YOUNGER THAN TWO YEARS IN MOTHERWELL, NELSON MANDELA METROPOLITAN MUNICIPALITY

PRP: Dr L Steenkamp
PI: Mr S McLaren

Your above-entitled application served at Research Ethics Committee (Human) for extension.

We take pleasure in informing you that the extension was approved by the Committee.

The ethics clearance reference number is **H15-HEA-DIET-002** and is valid for three years. Please inform the REC-H, via your faculty representative, if any changes (particularly in the methodology) occur during this time. An annual affirmation to the effect that the protocols in use are still those for which approval was granted, will be required from you. You will be reminded timeously of this responsibility, and will receive the necessary documentation well in advance of any deadline.

We wish you well with the project. Please inform your co-investigators of the outcome, and convey our best wishes.

Yours sincerely

CB Cilliers

Prof C Cilliers
Chairperson: Research Ethics Committee (Human)

cc: Department of Research Capacity Development
Faculty Officer: Health Sciences

Addendum D: Ethics approval letter Nelson Mandela Bay Department of Health

Province of the
EASTERN CAPE
HEALTH

Nelson Mandela Bay Health District
Private Bag X [illegible]
Greenacres
Port Elizabeth
6057
REPUBLIC OF SOUTH AFRICA

Enquiries : Dr L P MAYEKISO
Telephone : 041-[illegible]
Facsimile : 041-[illegible]
E-mail : [illegible]@gmail.com

Our Reference: RESEARCH/2015
Your Reference:
Date: 14 OCTOBER 2015

Ms S Mclaren

REQUEST FOR PERMISSION TO CONDUCT "ANTROPOMETRIC INDICATORS IN IDENTIFYING MALNUTRITION AMONG CHILDREN YOUNGER THAN TWO YEARS IN MOTHERWELL, NELSON MANDELA BAY HEALTH DISTRICT"

In response to your application for permission to conduct the above research study at facilities within the Nelson Mandela Bay Health District (NMBHD), permission is hereby granted with the following proviso:

There should be no negative impact on existing health service delivery operations. All required data should be collected by the Researcher or a designated fieldworker (whose name should be forwarded to the relevant Sub District Coordinator prior to data collection). The Sub District Coordinator, Mrs Siphokazi Mautu - 083 378 1942 and Mrs P Njalo, Facility Manager, Motherwell CHC 060 583 6676 should be contacted before your visit and this letter is to be presented when visiting the Motherwell Community Health Centre.

The Nelson Mandela Bay Health District, as the research site, will expect a copy of the final research report when the study is completed. If the duration of the research period is required to be extended, the NMBHD should be informed accordingly.

We would like to take this opportunity to wish you well for your research study.

DR L P MAYEKISO
CLINICAL GOVERNANCE MANAGER - NMBHD

Addendum E: Consent form

• PO Box 77000 • Nelson Mandela Metropolitan University
• Port Elizabeth • 6031 • South Africa • www.nmmu.ac.za

Nelson Mandela Metropolitan University

for tomorrow

Study to weigh and measure children at schools, creches and clinics

Ethics committee reference number: H15-HEA-DIET-002

CONSENT FORM

I, the undersigned, ______________________(**Name of Parent**/Caretaker/Legal guardian/Teacher)

of

____(**Name of child**)

give consent that _____________________ (Name of child) may participate in the project carried out by the Department of Dietetics in collaboration with the Department of Health.

I have read the invitation at the back of this page, I understand that the child will be weighed and measured and I agree that this child can partake in the study. I also know that my permission can be withdrawn at any time.

Signed at **Port Elizabeth** on ______________________ 201 (date)

Parent/ __________________(Name) ______________________(Signature) **x**
Caretaker/
Teacher if verbal agreement by parent

Witness: __________________(Name) ______________________(Signature)

To the mother/father/caretaker:

The Dietetics Department ask permission for your child to participate in a research study. Students from the university will weigh and measure the children in the class. If you do not agree to this, please inform the teacher. If you agree, please fill in your name and sign the form on the back at the **X**, and send it back to school.

Informed consent: Once you agree to let your child participate, your child will also be asked for his/her agreement. For further information and questions, please do not hesitate to contact the department or the research supervisor Dr Steenkamp (0828298418).

Participation in the research is voluntary. Your child will be weighed and measured by a trained student or fieldworker. This measurements will take 3 to 5 minutes to complete and will not hurt the child. The measurements may be repeated in the next three years in 6 month intervals in order to determine how well your child is growing. If your child resist the measurements and become upset, the researchers will not force him/her to participate.

Participation in the study is completely anonymous, and you have the right to withdraw from the study at any time. All names will be kept confidential. If your child is found to be at risk of malnutrition, your child will be referred to the nearest clinic for assessment and possible supplementation. Please remember to send the Road to Health clinic book to the crèche or school and to ask it back.

Ndiyavuma ukuba ndigcaciselwe ngokuba:

Olu luphando olucacisa into edibanisa ukukhula komntana nobunzima okanye ubude bakhe. Uvavanyo lokwenziwa ngabafundi besebe lweDietetics abasuka eNMMU.

Ukuba uyavuma ukuthatha ingxaxheba koluphando umntana wakho naye kuzofuneka avume. Unelungelo lokurhoxisa nanini na koluphando. Ukuthatha ingxaxheba kungentando yakho, ayisosinyanzeliso. Umntana kuzo kukhangelwa ubunzima nobude bakhe ngumfundi okanye umsebenzi oqeqeshiweyo. Oluvavanyo luthatha imizuzu emithatu uyotsho kwemihlanu ukwenziwa futhi lingaphinda phindwa kabini ngonyaka kule minyaka mithathu izayo. Olu vavanyo aluzomenzakalisa umntana. Ukuba umntana wakho uye wakhubeka waze akufuna ukuthatha ingxaxhebha akazo nyanzelwa. Amagama abantu abathatha ingxaxheba kolu phando awazokwaziwa ngabanye abantu ngaphandle kwaba baqeqeshelwe oluphando. Ukuiba kuye kwafumaniseka ukuba kukho ingxaki nokukhula komntana wakho uzokufumana uncedo olufanelekileyo

Xa unemibuzo malunga nophando nceda udibane ngomnxeba notishala womntana

Addendum F: Verbal information given to parents

The Dietetics department at Nelson Mandela Metropolitan University (NMMU) is conducting research in the community of Motherwell, Port Elizabeth. This research aims to find the relationship between body measurements and the risk of malnutrition in children less than two years old in the Eastern Cape. These body measurements are interpreted using standard weight for age (WFA), weight for height (WFH), length for age (LFA) Z-scores and mid-upper arm circumference (MUAC) measurements.

Your choice to include your child for participation in the research is voluntary. If you choose to allow your child to be involved in the study, you will be asked some basic questions on your ethnicity and socio-economic status. Your child will be weighed and measured by a trained health worker as part of normal growth monitoring and promotion. Measurements are non-invasive and no follow-up measurements are required by the researcher.

Participation in the study is completely anonymous, and you have the right to withdraw from the study at any time. Your anonymity and confidentiality will be maintained throughout the data collection, analysis and in any report or publication of the results of the research.

Once your child has been measured, you will receive immediate feedback regarding the nutritional state of your child. You have the right to access nutritional health service interventions, and you will be advised on any appropriate interventions should the measurement screening reveal a need.

Addendum G: WHO Simplified MUAC field table for male children

Simplified field tables

Arm circumference-for-age BOYS
3 months to 5 years (z-scores)

World Health Organization

Year: Month	Months	-3 SD	-2 SD	-1 SD	Median	1 SD	2 SD	3 SD
0: 3	3	10.7	11.6	12.5	13.5	14.5	15.6	16.7
0: 4	4	10.9	11.8	12.8	13.8	14.9	16.0	17.2
0: 5	5	11.1	12.0	13.0	14.1	15.2	16.3	17.5
0: 6	6	11.3	12.2	13.2	14.2	15.4	16.5	17.8
0: 7	7	11.4	12.3	13.3	14.4	15.5	16.7	18.0
0: 8	8	11.4	12.4	13.4	14.5	15.6	16.8	18.1
0: 9	9	11.5	12.4	13.4	14.5	15.7	16.9	18.2
0:10	10	11.5	12.5	13.5	14.6	15.7	17.0	18.3
0:11	11	11.6	12.5	13.5	14.6	15.8	17.0	18.3
1: 0	12	11.6	12.5	13.6	14.6	15.8	17.1	18.4
1: 1	13	11.6	12.6	13.6	14.7	15.8	17.1	18.4
1: 2	14	11.6	12.6	13.6	14.7	15.9	17.1	18.5
1: 3	15	11.7	12.6	13.6	14.7	15.9	17.2	18.5
1: 4	16	11.7	12.7	13.7	14.8	16.0	17.2	18.6
1: 5	17	11.7	12.7	13.7	14.8	16.0	17.3	18.6
1: 6	18	11.8	12.7	13.7	14.8	16.0	17.3	18.7
1: 7	19	11.8	12.8	13.8	14.9	16.1	17.4	18.8
0: 9	9	11.5	12.4	13.4	14.5	15.7	16.9	18.2
0:10	10	11.5	12.5	13.5	14.6	15.7	17.0	18.3
0:11	11	11.6	12.5	13.5	14.6	15.8	17.0	18.3
1: 0	12	11.6	12.5	13.6	14.6	15.8	17.1	18.4
1: 1	13	11.6	12.6	13.6	14.7	15.8	17.1	18.4
1: 2	14	11.6	12.6	13.6	14.7	15.9	17.1	18.5
1: 3	15	11.7	12.6	13.6	14.7	15.9	17.2	18.5
1: 4	16	11.7	12.7	13.7	14.8	16.0	17.2	18.6
1: 5	17	11.7	12.7	13.7	14.8	16.0	17.3	18.6
1: 6	18	11.8	12.7	13.7	14.8	16.0	17.3	18.7
1: 7	19	11.8	12.8	13.8	14.9	16.1	17.4	18.8
1: 8	20	11.9	12.8	13.8	14.9	16.1	17.4	18.8
1: 9	21	11.9	12.8	13.9	15.0	16.2	17.5	18.9
1:10	22	11.9	12.9	13.9	15.0	16.3	17.6	19.0
1:11	23	12.0	12.9	14.0	15.1	16.3	17.6	19.1
2: 0	24	12.0	13.0	14.0	15.2	16.4	17.7	19.2
2: 1	25	12.1	13.0	14.1	15.2	16.4	17.8	19.2
2: 2	26	12.1	13.1	14.1	15.3	16.5	17.9	19.3
2: 3	27	12.2	13.1	14.2	15.3	16.6	17.9	19.4
2: 4	28	12.2	13.2	14.2	15.4	16.6	18.0	19.5
2: 5	29	12.3	13.2	14.3	15.4	16.7	18.1	19.6
2: 6	30	12.3	13.3	14.3	15.5	16.8	18.1	19.7
2: 7	31	12.3	13.3	14.4	15.5	16.8	18.2	19.7
2: 8	32	12.4	13.3	14.4	15.6	16.9	18.3	19.8

Addendum H: WHO Simplified MUAC field table for female children

Simplified field tables

Arm circumference-for-age GIRLS
3 months to 5 years (z-scores)

World Health Organization

Year: Month	Months	-3 SD	-2 SD	-1 SD	Median	1 SD	2 SD	3 SD
0: 3	3	10.2	11.1	12.0	13.0	14.2	15.4	16.8
0: 4	4	10.5	11.3	12.3	13.4	14.5	15.8	17.2
0: 5	5	10.7	11.5	12.5	13.6	14.8	16.1	17.6
0: 6	6	10.8	11.7	12.7	13.8	15.0	16.3	17.8
0: 7	7	10.9	11.8	12.8	13.9	15.1	16.5	18.0
0: 8	8	11.0	11.9	12.9	14.0	15.2	16.6	18.1
0: 9	9	11.0	11.9	12.9	14.1	15.3	16.7	18.2
0:10	10	11.1	12.0	13.0	14.1	15.4	16.7	18.2
0:11	11	11.1	12.0	13.0	14.2	15.4	16.8	18.3
1: 0	12	11.1	12.1	13.1	14.2	15.4	16.8	18.3
1: 1	13	11.2	12.1	13.1	14.2	15.5	16.8	18.3
1: 2	14	11.2	12.1	13.2	14.3	15.5	16.9	18.4
1: 3	15	11.3	12.2	13.2	14.3	15.6	16.9	18.4
1: 4	16	11.3	12.2	13.3	14.4	15.6	17.0	18.5
1: 5	17	11.4	12.3	13.3	14.4	15.7	17.0	18.5
1: 6	18	11.4	12.3	13.4	14.5	15.7	17.1	18.6
1: 7	19	11.4	12.4	13.4	14.5	15.8	17.1	18.7
1: 2	14	11.2	12.1	13.2	14.3	15.5	16.9	18.4
1: 3	15	11.3	12.2	13.2	14.3	15.6	16.9	18.4
1: 4	16	11.3	12.2	13.3	14.4	15.6	17.0	18.5
1: 5	17	11.4	12.3	13.3	14.4	15.7	17.0	18.5
1: 6	18	11.4	12.3	13.4	14.5	15.7	17.1	18.6
1: 7	19	11.4	12.4	13.4	14.5	15.8	17.1	18.7
1: 8	20	11.5	12.4	13.5	14.6	15.8	17.2	18.7
1: 9	21	11.6	12.5	13.5	14.7	15.9	17.3	18.8
1:10	22	11.6	12.6	13.6	14.7	16.0	17.4	18.9
1:11	23	11.7	12.6	13.7	14.8	16.1	17.5	19.0
2: 0	24	11.7	12.7	13.7	14.9	16.1	17.5	19.1
2: 1	25	11.8	12.7	13.8	15.0	16.2	17.6	19.2
2: 2	26	11.8	12.8	13.9	15.0	16.3	17.7	19.3
2: 3	27	11.9	12.9	13.9	15.1	16.4	17.8	19.4
2: 4	28	11.9	12.9	14.0	15.2	16.5	17.9	19.5
2: 5	29	12.0	13.0	14.1	15.3	16.6	18.0	19.6
2: 6	30	12.0	13.0	14.1	15.3	16.6	18.1	19.7
2: 7	31	12.1	13.1	14.2	15.4	16.7	18.2	19.8
2: 8	32	12.1	13.1	14.2	15.4	16.8	18.3	19.9

Addendum I: Anthropometry manual for fieldworkers training

Anthropometry Manual

for

Field Workers

Motherwell

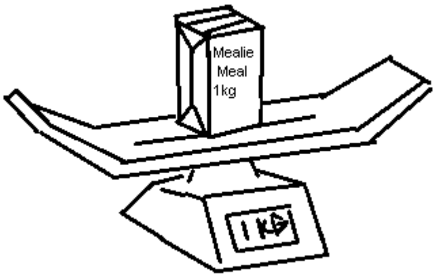
2015

1. Measuring Weight

As children get older, they get bigger. One method for deciding whether a child is growing well is to check their weight, as a child growing in size will also grow heavier. The child's weight can then be compared to the expected weight for their age, which is most often done using the Weight for Age Growth Chart in the Road to Health Book (RTHB).

Weighing infants:

Step 1: Calibrate the scale to ensure that the weight reading is accurate. Test the accuracy of the scale by weighing an object with a known weight (for example, a 1kg packet of mealie meal). If the weight displayed is incorrect, calibrate the scale.



Step 2: Ask the infant's mother or caregiver to remove the infant's outer clothes (jackets, pants, shoes).

Step 3: Turn the infant scale on, and place a clean Chux pad on the scale. Press "Tare" to "zero" the scale before placing the infant on the scale.

Step 4: Place the infant on the centre of the scale, lying on his or her back. Allow the weight reading to settle then record the weight on the Weight for Age Growth Chart in kilograms (kg) to the nearest 0.01kg (10g).

Weighing Children:

Step 1: Calibrate the scale to ensure that the weight reading is accurate. Test the accuracy of the scale by weighing an object with a known weight (for example, a 1kg packet of mealie meal). If the weight displayed is incorrect, calibrate the scale.

Step 2: Ask the child's mother or caregiver to remove the child's outer clothes (jackets, pants, shoes).

Step 3: Put the child on the standing scale, allow the weight reading to settle then record the weight on the Weight for Age Growth Chart in kilograms (kg) to the nearest 0.01kg (10g).

2. Measuring Length/height

Length and height are very important indicators of growth in children. This process requires two people (a "recorder" and "examiner") for accuracy and involves the caretaker or parent to ensure that the baby feels safe and comfortable. Length is measured using an infantometer (length board or foldable length mat).

Measuring infants:

Step 1: Remove the infant's outer clothes, undo braided hairstyles, and place a clean Chux pad on the infantometer length board

Step 2: The child must be positioned with the feet orientated toward the movable foot piece, and the head resting against the stationary head piece. One researcher supports the head and records the measurement while the other positions the feet and examines the length measurement. Infants may become agitated (irritable and crying) in a recumbent (lying) and vulnerable position, so it is advised that the infant's caretaker position her or himself between the recorder and examiner

Step 3: The infants back and legs must be straight, with the sole of the foot at a right angle to the length board for a reading to be accurate. Extremely uncomfortable children may be recorded with only one straight leg. A gentle stroke along the inside of the infant's foot may help to get it into the correct position

Step 4: Shift the foot piece up against the infants' feet and take the measurement. Record the length on the Length/Height for Age Growth Chart, in centimetres (cm) to the nearest 0.1cm (1mm).

Measuring Children:

Children who are able to stand can be measured using a stadiometer (adjustable height stick):

Step 1: Remove the child's shoes and head dress (hats, braided hairstyles)

Step 2: The child needs to stand with his or her back to the height stick. The heels of the feet, bum, back and head must touch the height stick.

Step 3: While the child breathes in, gently lower the horizontal sliding piece onto the top of the child's head. Read and record the height in centimetres (cm), to the nearest 0.1cm (1mm) in the Height for Age Growth Chart in the RTHB.

4. Measuring Mid-upper Arm Circumference (MUAC)

MUAC is also measured using a non-stretchable measuring tape. MUAC is an extremely easy and reliable tool for diagnosing severe acute malnutrition (SAM) and moderate acute malnutrition (MAM).

Step 1: Begin standing on the right hand side of the infant or young child, the infant's weight evenly distributed, shoulders relaxed and right arm hanging freely at the side.

Step 2: Find the acromion process at the end of the shoulder and mark it with a cosmetic pen. From this point, place a tape measure along the length of the upper arm to find the numerical midpoint. Mark this point with the cosmetic pen.

Step 3: Move the infant's arm into a position where it is bent perpendicularly at the elbow, palm facing upward. Measure the circumference around the infant's arm at the marked midpoint and record to the nearest 0.1cm (1mm).

5. Interpreting Weight

Growth is interpreted using the growth charts in the RTHB. Weight is used to calculate the Weight for Age (WFA) Z-score. Weight for Age is used to decide whether a child is UNDERWEIGHT (the child is small for his or her age). It is generally assumed that underweight is an acute (short term or recently developed) result of under nutrition.

Position on Growth Chart	Interpretation
Above +3 line	Possibly overweight: confirm with WFL Z-score
Above +2 line	
Between -2 and +2 lines	Normal weight (growing well)
Below -2 line	Moderately UNDERWEIGHT
Below -3 line	Severely UNDERWEIGHT

6. Interpreting Length/height

Length or height is a measurement of growth which is interpreted using the Length/Height for Age Growth Chart. Length or Height for Age are used to decide whether a child is very tall for his or her age (which might be the cause of a false "overweight"), of average height, or STUNTED. Stunting is very common and is assumed to be the result of chronic (long-term) under nutrition. Stunted children will often have a low WFA Z-score as they are smaller than the average, normally-growing child.

Position on Growth Chart	Interpretation
Above the +2 line	Tall for age
Between the +2 and -2 lines	Normal height (growing well)
Below the -2 line	Moderately STUNTED
Below the -3 line	Severely STUNTED

7. Interpreting Weight for Length/Height

Weight for Length (WFL) or Weight for Height (WFH) growth charts are used to tell if a child is WASTED. Wasting is often confused with underweight, but they are not exactly the same thing. Wasting means that there is “not enough meat on the bones”, as in, the child is thin but of a normal height for his or her age. This is an acute (recently developed) condition, which is why we call wasting Moderate Acute Malnutrition (MAM) and Severe Acute Malnutrition (SAM). However, a child may be underweight for either one of two reasons: either they are wasted, or they are small for their age. MAM and SAM require urgent nutritional and medical intervention!

Position on Growth Chart	Interpretation
Above +2 line	Overweight
Between +2 and -2 line	Normal weight for height (growing well; or both stunted and underweight at the same time!)
Below -2 line	Moderate Acute Malnutrition
Below -3 line	Severe Acute Malnutrition

8. Interpreting Mid-Upper Arm Circumference (MUAC)

MUAC is another way to decide whether or not a child is WASTED. It is an independent criterion for diagnosing MAM and SAM. The interpretations below are only applicable to children between the ages of six months and five years. There is no growth chart for MUAC in the RTHB, but a table for recording MUAC can be found on page 19 of the RTHB.

MUAC Measurement (6 to 59 months)	Interpretation
More than 12.5cm	Normal growth (not wasted)
Between 11.5cm and 12.5cm	Moderate Acute Malnutrition
Less than 11.5cm	Severe Acute Malnutrition

9. Clinical Signs of Malnutrition

Anthropometry (measuring the human body) is the “gold standard” for determining nutritional status, but it is still important to be able to recognise the signs and symptoms of malnutrition in the field, in order to make the best decisions for intervention quickly.

Emaciation/Wasting is the name given to the condition when people are so thin that they look skeletal. The cheek bones and temples become very pronounced, and in infants, the fontanel on the top of the head is often indented (also commonly caused by dehydration which is associated with malnutrition). The arms and legs may appear very thin, and ribs may be easily visible through the skin.

Oedema is fluid retention and occurs frequently in severely malnourished children. Children with oedema will have puffy, swollen feet, hands or face. Test for oedema by pressing gently into the skin. If your finger leaves an imprint or pit, the child has oedema. Children with bilateral (on both sides), pitting oedema must be referred to hospital immediately.

Hair becomes very brittle and weak. It is pulled out easily, and often looks patchy. It may also lose some of its colour and appear orange.

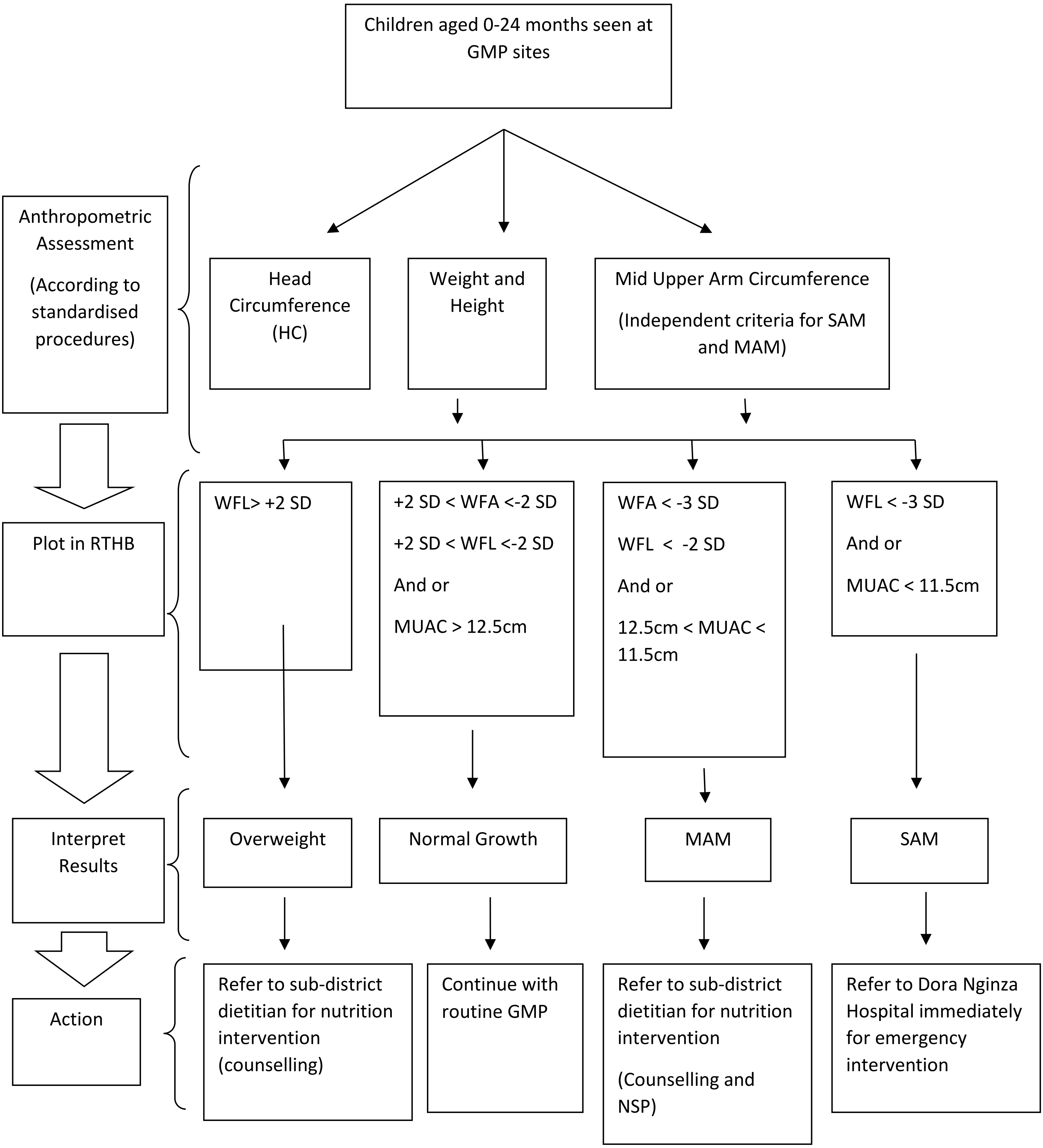
Skin is marked by dry patches that might be red and bleeding in very bad cases. This is known as dermatitis.

The mouth might present with painful sores at the corners of the lips, known as angular stomatosis, which is caused by a weakened immune system and vitamin B deficiency. The tongue might be pale or covered in a white or red “fur”, which is a sign of oral infection caused by a weakened immune system. Mouth problems can cause appetite problems, which make malnutrition worse.

Loss of appetite is a common complication of starvation. Ask the mother or caregiver how the child is eating to evaluate appetite, or perform an appetite test using a ready to use therapeutic food (RUTF). Malnourished children with a WFH Z-score below the -3 line, or a MUAC of less than 11.5cm, as well as loss of appetite, must be referred to hospital immediately.

10 Protocol for Nutrition Intervention

The flow chart below will guide you on what action to take depending on the outcome



Addendum J: Draft guidelines for malnutrition screening in the Eastern Cape

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Nelson Mandela Metropolitan University

for tomorrow

ANTHROPOMETRY

Screening children for malnutrition

New Draft Guidelines for the Eastern Cape

“[Growth monitoring is the] regular measurement, recording and interpretation of a child’s growth in order to counsel, act and follow-up results with the purpose of promoting child health, human development and quality of life”

Department of Health (2013)

Anthropometry is the most universally applicable, non-invasive method of assessing growth in children

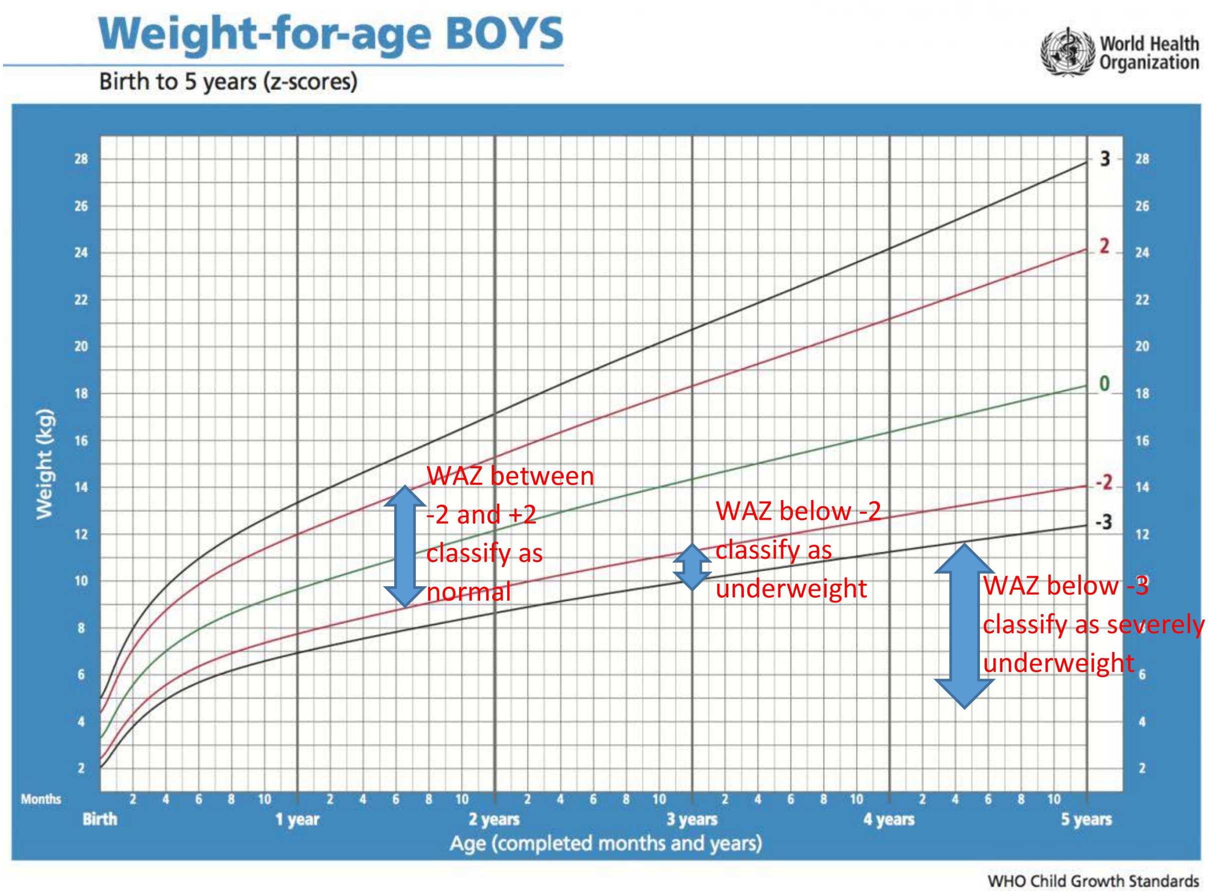
De Onis (2015).

Weight

In 2006, the WHO revised the international growth reference for infant and under-five child growth. The result was the WHO child growth standard, used in South Africa to assess the nutritional status and growth of children.

The weight of infants and children is assessed using a scale. Weight is interpreted using the WHO standard weight for age (WFA) Z score chart. This chart is used from birth to five years, thereafter the WHO reference is used. There are separate charts for boys and girls. The boys WFA Z score chart is shown below.

Once the weight is taken, it is compared to the standard for the child's age at the time of measurement. If the WFA is below the -2 line, the child is classified as underweight. A weight plotted above the -2 line is considered normal. The interpretations are included on the growth chart below. Weight should be assessed at every clinic visit for children younger than five years.

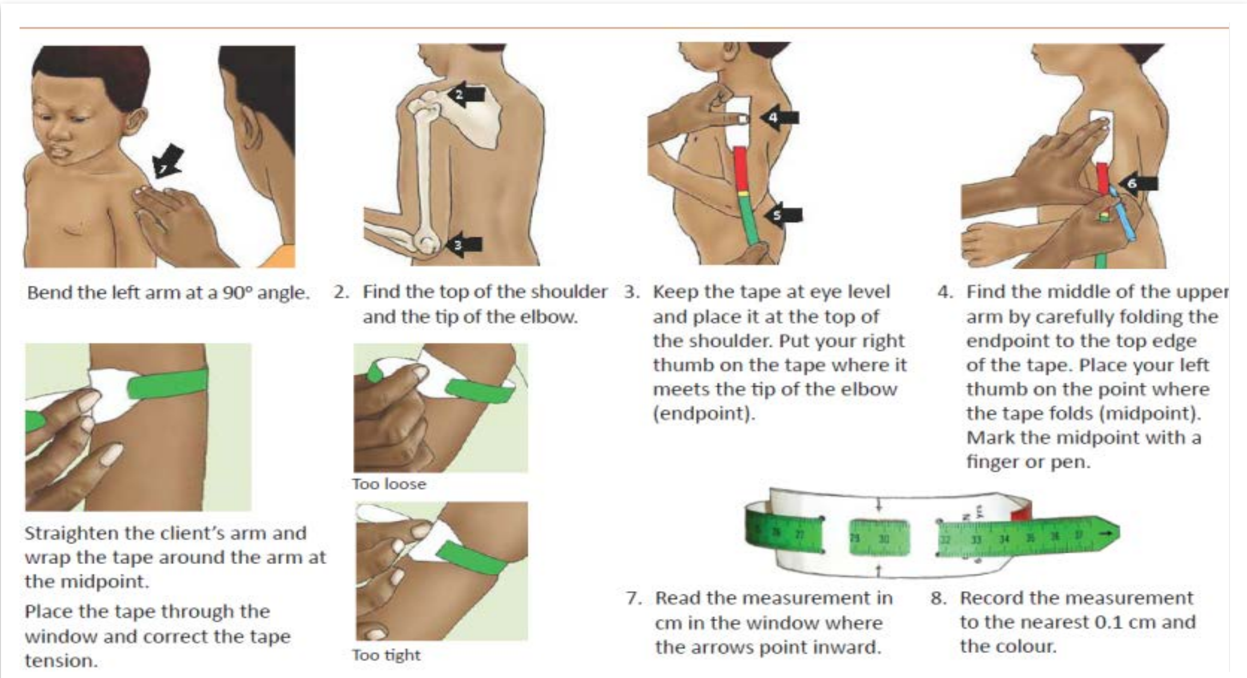


Mid-Upper Arm Circumference (MUAC)

MUAC is assessed using a flexible tape measure. It is a measurement of the amount of bone, muscle, fat and skin on the arm. MUAC may be used as an indirect method to assess the degree of wasting of fat and muscle stores in infants and young children. Weight for length is the gold standard but a lot of fieldworkers in EC do not measure because they have no access to scales. MUAC is a cheap, simple and effective alternative.

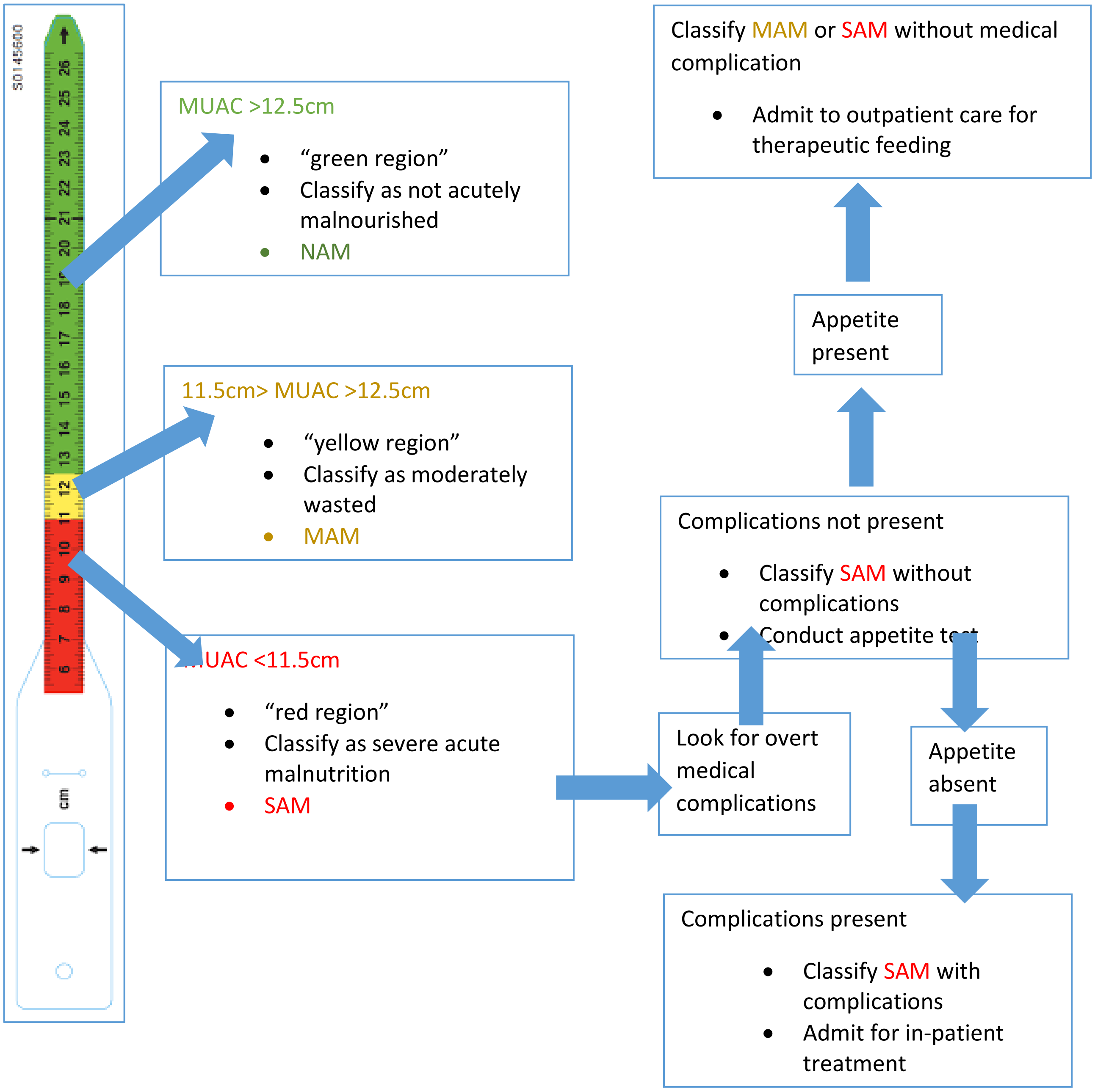
A MUAC measurement of less than 11.5cm is classified as severe acute malnutrition. A measurement that is between 11.5cm and 12.5cm is classified as moderate acute malnutrition. A MUAC of greater than 12.5cm is considered not acutely malnourished. Children younger than five years should have their MUAC assessed every three months.

The measuring technique for MUAC is given in the series of diagrams below, and the interpretation of MUAC is given in the diagram on the next page.

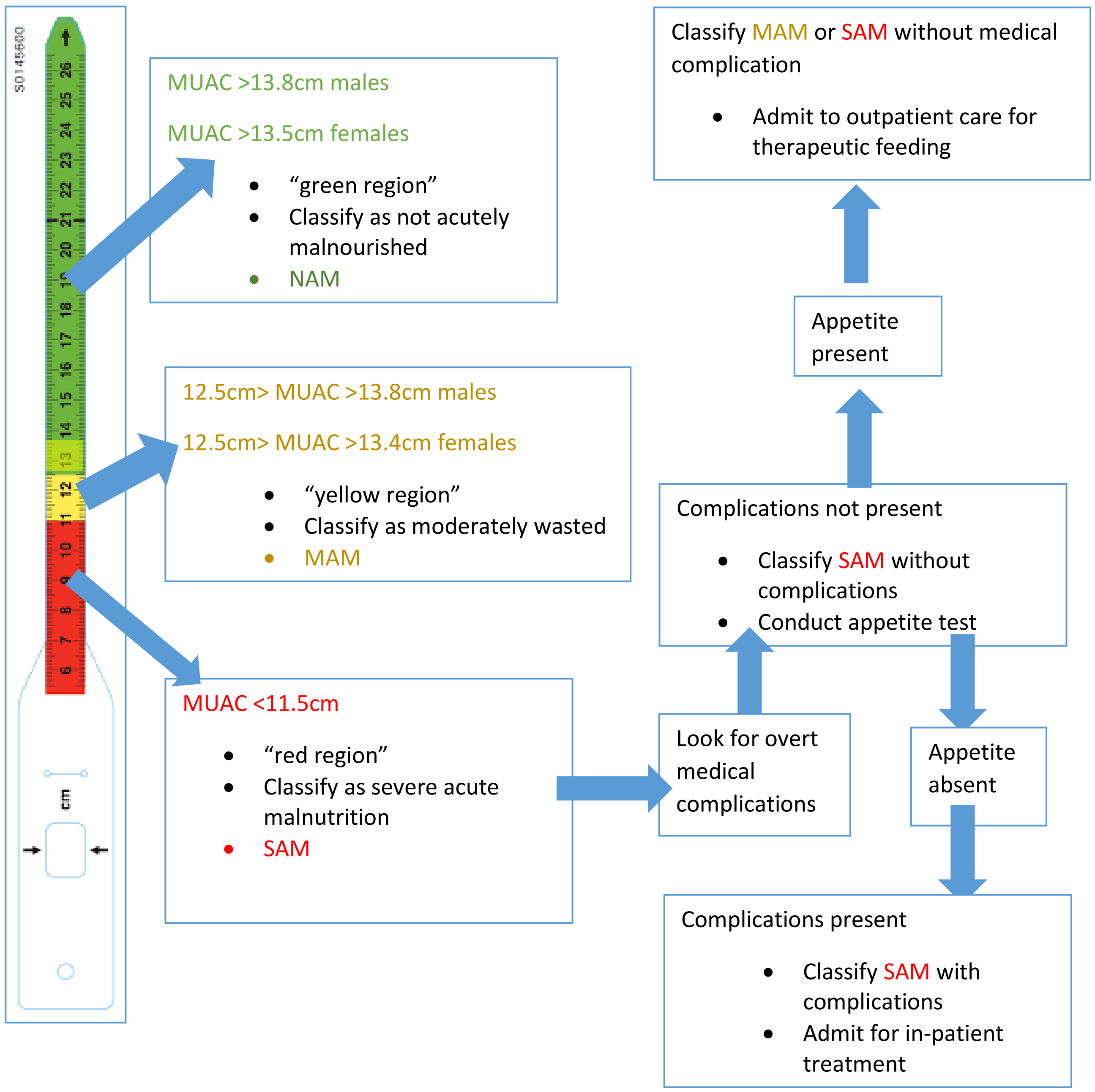


The use of the current MUAC guidelines are given in the diagram below.

This is the way that MUAC was done and interpreted.



However, a study conducted in Motherwell, in the Eastern Cape, showed that these cut off values were not sensitive enough to detect malnutrition. New MUAC cut off values for MAM are presented in the figure below



Length

Weight changes constantly, but children grow in length or height more gradually. Measuring length refers to infants who are too young to stand unassisted, and height refers to how tall a child is when they are able to stand on their own (at around 24 months old). Length is measured using an infantometer or length board, as described below. Height may be assessed using a stadiometer or graduated vertical height stick.

- Two people taking measurement
- Clothes on, but shoes removed
- Toes pointing upwards
- Head still, body in straight line

Length and height are interpreted using the WHO standard length for age (LFA) chart, shown below. The length of the child, measured in centimetres, is plotted against the age of the child at the time of measurement. If the plotted point is below the -2 line, the child is classified as stunted. If the LFA is below the -3 line, the child is severely stunted.