THE RELATIONSHIP BETWEEN ANTHROPOMETRIC INDICATORS FOR MALNUTRITION STATUS, AND BLOOD PRESSURE PARAMETERS IN ELLISRAS RURAL CHILDREN AGED 5 TO 12 YEARS: ELLISRAS LONGITUDINAL STUDY

by

NTHAI ELFAS RAMOSHABA

[redacted]

DISSERTATION

submitted in fulfilment of the requirements for the degree of

MASTER OF SCIENCE

in

PHYSIOLOGY

in the

FACULTY OF SCIENCE AND AGRICULTURE,

SCHOOL OF MOLECULAR AND LIFE SCIENCES,

at the

UNIVERSITY OF LIMPOPO

SUPERVISOR : PROF KD MONYEKI

CO-SUPERVISOR : PROF L HAY (SMU)

2016

DEDICATION

I dedicate this dissertation to my family and friends. I would like to express special gratitude to my father (Sekhwantha Isaac Ramoshaba) and mother (Makoma Agnes Ramoshaba), who continuously encouraged and supported me through my studies. My brother (Thomas Ramoshaba) and sister (Sebolawe Maria Ramoshaba) for being supportive. Futhermore, I also dedicate this dissertation to my grandmother (Maite Welhemina Rakoma) and uncle (Khubidu Elias Rakoma) for their great support and motivation through my studies. I would also like to thank my dearest friend Surprise “Ntsekana” Moela for the words of encouragement and being there thoughtout my studies.

DECLARATION

I declare that THE RELATIONSHIP BETWEEN ANTHROPOMETRIC INDICATORS FOR MALNUTRITION STATUS, AND BLOOD PRESSURE PARAMETERS IN ELLISRAS RURAL CHILDREN AGED 5 TO 12 YEARS: ELLISRAS LONGITUDINAL STUDY is my own work and that all sources that I have used or quoted have been indicated by means of complete reference and that this work has not been submitted before for any other degree at any other institution.

……………………………….. ………………………….

Full names Date

ACKNOWLEDGEMENTS

- I would firstly like to give thanks to my Ancestors and God for the knowledge, strength and guidance during the entire period of my study.
- My parents (Isaac and Agnes Ramoshaba) for their support, motivation and entrusting me.
- My brother (Thomas Ramoshaba) and sister (Sebolawe Ramoshaba) for their support.
- I would like to thank Prof KD Monyeki and Prof L Hay for their support, critical revision of the dissertation for important intellectual content, administrative, technical and material support, such as supervision of the study.
- University of Limpopo, Department of Physiology and Environmental Health staff members and students
- Sefako Makgatho Health Science University department of Human Physiology staff members.
- Financial support received from Vrije University, Amsterdam, The Netherlands, the University of Limpopo, South Africa and National Research Foundation is acknowledged with gratitude. Any opinion, findings and conclusions or recommendations expressed in this material are those of the authors and therefore the above mentioned funding sources do not accept any liability in regard thereto.
- The authors are indebted to the Ellisras Longitudinal Study administrators Mr TT Makata, Seleka SP, Seleka MS and Mr Makata W for coding the data.
- Monyeki MS and Malatji MJ (Makgoka Secondary School, English educator, Limpopo Province) are thankfully acknowledged for editing this dissertation.

ABSTRACT

Cardiovascular diseases (CVDs) are major public health problems nowadays in Africa. From prospective studies, it is also known that risk factors for CVDs start early in life and increase morbidity and mortality in sub-Saharan African adults. Mostly the risk factors of CVDs are malnutrition and hypertension. Economic development in South Africa leads to lifestyle changes that contribute to a high prevalence of high blood pressure (BP) and malnutrition. However, little is known about the relationship of anthropometric indicators and BP in children from the developing countries. Therefore the aim of this study was to determine the association between anthropometrics indicators and BP among rural children in Ellisras area of Limpopo province, South Africa. All 1961 children (n=1029 boys, n=932 girls) aged 5-12 years underwent anthropometric and BP measurements using standard procedure. Receiver operating characteristics (ROC) curve was used to assess the ability of anthropometric indicators to discriminate children with high BP. ROC was used to determine the area under curve (AUC), cut-off value, sensitivity and specificity for underweight in children for each age and gender. Linear regression was used to assess the relationship between anthropometric indicators and BP. ROC curve showed that height (AUC = 0.700, 95%Cl 0.581 to 0.818), SH (AUC= 0.690, 95%Cl 0.573 to 0.786) and SH/H (AUC=0.670, 95% 0.533 to 0.807) can significantly ($P<0.05$) identify Ellisras children with hypertension. AUC for neck circumference (NC) (0.698), mid upper arm circumference (MUAC) (0.677) and body mass index (BMI) (0.636) for boys were statistically significant ($P<0.05$) for high systolic blood pressure (SBP), while in girls AUC of BMI was not significant ($P>0.05$) for high diastolic blood pressure (DBP). The regression analysis showed a positive significant ($P<0.05$) association of SBP with NC (β=0.764, 95%CI 0.475 to 1.052) and MUAC (β=1.286, 95% Cl 0.990 to 1.581) for unadjusted and adjusted age and gender. NC (β=0.628 95% Cl 0.303 to 0.953) and MUAC (β=1.351 95% CI 1.004 to 1.697) showed a significant association with SBP. However, MUAC had a significant association with DBP for both unadjusted and adjusted age and gender. Sitting height (SH) was significantly associated with SBP (β = 0.134, 95% Cl 0.210 to 0.416) and DBP (β = 0.088, 95% Cl 0.086 to 0.259) for unadjusted. After adjusted for age and gender, SH was significantly associated with both SBP (β = 0.161, 95% Cl 0.220 to 0.532) and DBP (β = 0.101, 95% Cl 0.066 to 0.329). There was a positive significant association between BP and anthropometric indicators in this population study, though the association of DBP and NC disappeared after adjustments for age and gender. Furthermore, there is a positive significant association between DBP and SBP with the components of height amongst Ellisras rural children. NC and MUAC are the simplest techniques with good interrater reliability and could be used to screen underweight in children.

KEY CONCEPTS

Malnutrition; Neck circumference; Mid upper arm circumference; Cardiovascular disease; Blood pressure; Components of height; Rural South African children.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

AUC- Area under curve

BP- Blood pressure

CVD- Cardiovascular diseases

DBP- Diastolic blood pressure

ELS- Ellisras Longitudinal Study

ISAK- International Society for the Advancement of Kinanthropometry

MUAC- Mid upper arm circumference

NHANES- National Health and Nutrition Examination Survey III

NC- Neck circumference

ROC- Receiver operating characteristics

SBP- Systolic blood pressure

SH- Sitting height

SH/H- Sitting to height ratio

CHAPTER 1

PROBLEMS AND AIMS OF THE STUDY

1.1. PROBLEM STATEMENT

Malnutrition (underweight or obesity) and hypertension in children are associated with the risk of cardiovascular diseases (CVDs) in adulthood (WHO, 2005). The classification of malnutrition in low resource settings in later childhood and adolescence is currently unsatisfactory because of the lack of suitable cut off points. However, body mass index (BMI) cut off points for malnutrition is widely used in children, though it does not account for the central pattern of adiposity observed (Kemper et al., 2012). A number of cross sectional studies have shown that other anthropometric indicators (BMI, neck circumference, mid upper arm, waist girth, hip girth, upper arm muscle area and skinfolds thickness) for malnutrition are associated with blood pressure (BP) in children from developed countries (Ben-Noun and Laor, 2003; Zhou et al., 2009). Therefore, the need to establish cut off points for other relevant anthropometric indicators of malnutrition in rural South African children is vital. Furthermore, the childhood relationships between anthropometric indicators and BP, could potentially shed light on the risk of CVDs in adult rural South African populations.

1.2. RATIONALE

Cardiovascular diseases (CVDs) are major public health concerns at present. From prospective studies, it is also known that risk factors for CVDs commence early in life and increase morbidity and mortality in adulthood (Twisk et al., 2000; Kemper et al., 2012). Blood pressure (BP) is a physiological parameter that has been associated with CVDs, specifically if it changes dramatically over time. In addition, it has been reported that growth proportions and malnutrition can influence the changes in BP levels in children (Zhang et al., 2015).

Sitting height (SH), SH to height ratio (SH/H), neck circumference (NC) and mid upper arm circumference (MUAC) are the most commonly used parameters to represent growth proportion and malnutrition in a population. Thus, high SH/H indicates relatively shorter legs for total stature and low SH/H indicates relatively long legs for total stature (Fredriks et al., 2005). A number of studies have reported on close association of BP with body size and malnutrition, while greater height is correlated with BP in children and adolescents (Zhang et al., 2015). Recently, Montagnese et al. (2014) reported a positive significant association between BP and SH in Italian adult populations. Regnault et al. (2014) also reported that SH was significantly associated with BP in childhood. It is well known that BP is associated with malnutrition in children and adolescents (Genovesi et al., 2011). However, in malnourished children with different statures, little is known about the relationship between BP and different statures in rural South African children.

A number of studies established NC and MUAC cut off point for malnutrition using BMI >85 percentiles in children from western world. Recently, Cole et al. (2000; 2007) established international cut off point for BMI in children to diagnose malnutrition. However, little is known in African population about the relevant anthropometric variables cut-off points for malnutrition based on internationally BMI cut-off points.

1.3. AIM AND OBJECTIVES OF THE STUDY

The aim of this study was to determine the association between anthropometrics indicators and blood pressure among rural children in Ellisras area in Limpopo province, South Africa.

The objectives of the study were to:

i. test for period of measurements effect of all the anthropometric indicators (NC, MUAC, Height, Weight, SH and SH/H) to be used in the study.
ii. investigate the prevalence of malnutrition using international BMI cut off points.
iii. compare the SH and SH/H of Ellisras children with reference data (National Health and Nutrition Examination Survey III)
iv. determine the association between BP and anthropometric indicators (NC, MUAC, SH and SH/H) among Ellisras rural children aged 5 -12 years.
v. determine the sensitivity and specificity of NC and MUAC based on BMI international cut off points among Ellisras rural children.

1.4. SCIENTIFIC CONTRIBUTION

The anthropometric indictor cut off points for malnutrition in this study will assist in eliminating false negative and false positive diagnosis of this condition. Furthermore, it will help African children to familiarise themselves with their health status using less expensive equipment. In addition, the relationship between these anthropometrics indicators and BP will help to uproot the dynamics of CVDs among a paediatric population in rural South Africa. This study complements the mission and vision of the World Heart Foundation to reduce mortality from CVDs by 25% in 2025.

1.5. STRUCTURE OF THE DISSERTATION

I. Chapter 1 - Problems and aim of the study
II. Chapter 2 - Literature review
III. Chapter 3 - Materials and methods
IV. Chapter 4 – Results and Discussion
V. Chapter 5 – Introduction, summary, Conclusion and recommendations
VI. Articles published and submitted to International peer review Journal will be compiled as an addendum

1.6. REFERENCES

Ben-Noun L, Laor A. (2003). Relationship of neck circumference to cardiovascular risk factors. *Obes Res*, 11: 226-231.

Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. (2000). Establishing a standard definition for child overweight and obesity worldwide: International survey. *BMJ*, 320:1240-1243.

Cole TJ, Flegal KM, Nicholls D, Jackson AA. (2007). Body mass index cut - offs to define thinness in children and adolescents: International survey. *BMJ*, 335:194. doi: 10.1136/bmj.39238.399444.55.

Fredriks AM, Van Buuren S, Van Heel WJM, Dijkman-Neerincx RHM, Verloove-Vanhorick SP, Wit JM. (2005). Nationwide age references for sitting height, leg length, and sitting height/height ratio, and their diagnostic value for disproportionate growth disorders. *Arch Dis Child*, 90: 807- 812.

Genovesi S, Antolini L, Gallieni M, Aiello A, Mandal SK, Doneda A, Giussani M, Stella A, Tucci B, Valsecchi MG. (2011). High prevalence of hypertension in normal and underweight Indian children. *J Hypertens*, 29: 217- 221.

Kemper HC, Koppes LL, De Vente W, Van Lenthe FJ, Van Mechelen W, Twisk JW. (2012). Effects of health information in youth and young adulthood on risk factors for chronic diseases-20-year study results from the Amsterdam Growth and Health Longitudinal Study. *Prev Med*, 35: 533 - 539.

Montagnese C, Nutile T, Marphatia AA, Grijalva-Eternod CS, Siervo M, Ciullo M. (2014). Body composition, leg length and blood pressure in rural Italian population; a test of the capacity-load model. *Nutr Metab Cardiovasc Dis*, 24: 1204 - 1212.

Regnault N, Kleinman KP, Rifas-Shiman SL, Lengenberg C, Lipshultz SE, Gillman MW. (2014). Components of height and blood pressure in childhood. *Int J Epidemol*, 43:149-159.

Twisk JW, Kemper HC, Van Mechelen W. (2000). Tracking of activity and fitness and the relationship with cardiovascular disease risk factors. *Med Sci Sports Exerc*, 32: 1455-1461.

World Health Organization. (2005). Preventing chronic diseases: A Vital Investment: WHO Global Report.

Zhang Y, Zhao J, Chu Z, Wang L. (2015). The association between components of height and blood pressure among children and adolescents in Shandong, *China. Int J Cardiol*, 182:18-19.

Zhou Z, Hu D, Chen J. (2009). Association between obesity indices and blood pressure or hypertension: Which index is the best? *Public Health Nutr*, 12: 1061-1071.

CHAPTER 2

LITERATURE REVIEW

2.1. Introduction

2.2. Malnutrition

2.3. Blood pressure

2.4. Relationship of different anthropometric indicators to blood pressure

2.5. Components of heights and blood pressure

2.6. Receiver operating curve

2.7. Summary

2.8. References

2.1. INTRODUCTION

Cardiovascular diseases (CVDs) are major public health problems in Africa nowadays. From prospective studies, it is known that risk factors for CVDs start early in life and increase morbidity and mortality in sub-Saharan African adults (Sliwa et al., 2008; Twagirumukiza et al., 2011). The risk factors of CVDs are mainly malnutrition and high blood pressure (BP). Early intervention and diagnoses of these factors of CVDs will be beneficial to the sub-Saharan of African countries.

Malnutrition has been diagnosed using anthropometric indicators such as waist circumference (WC), hip circumference (HC), body mass index (BMI), neck circumference (NC), mid upper arm circumference (MUAC) and skinfolds in population studies (De Almeida et al., 2003; Plowman and Smith, 2011; Hingorjo et al., 2012). However, the classification of malnutrition in low resource settings is currently unsatisfactory in late childhood and adolescence because of lack of suitable cut off points.

High BP has been mostly diagnosed using WHO, (2000) cut off points in adults. However, in children and adolescents, the Task Force on Blood Pressure Control in Children, commissioned by the National Heart, Lung, and Blood Institute (NHLBI) of the National Institutes of Health (NIH), introduced the standard cut off points for diagnosing children with high blood pressure. Therefore these cut off points will be used in this study.

Both longitudinal and cross sectional studies have shown that these anthropometric indicators were associated with BP in adults in both developing and developed countries (Ben and Laor, 2004; Kapoor et al., 2012). Recently, NC, MUAC, SH and SH/H were reported to be having a significant association with BP in children from developed countries (Nafiu et al., 2014; Regnault et al., 2014). However, the association between NC, MUAC, SH and SH/H with BP has not been studied extensively in children from Ellisras rural areas and Sub-Saharan Africa.

2.2. MALNUTRITION

Malnutrition is a broad term and refers to both over-nutrition (overweight or obesity) and undernutrition (underweight or thinness).

Overweight - can be defined as weight that is higher than healthy or much body fat than is optimally required. Overweight can be caused by the following different factors where some of these factors are controllable and others are non-controllable.

Non-controllable factors for overweight are (Bleich et al., 2008):

- Age
- Genetics
- Gender

Controllable factors for overweight are (Patrick et al., 2004):

- Lifestyle changes
- Imbalance of energy in the body
- Environmental
- Sedentary lifestyle
- Illness

Underweight – can be described as weight that is less than the healthy weight based on WHO (2000) cut off points. It can also be caused by the following different factors where some of these factors are controllable and others are not controllable (Blössner and de Onis, 2005).

Non-controllable factors for underweight are:

- Genetics

Controllable factors for underweight are:

- Lack of food
- Metabolism
- Illness

These conditions (overweight and underweight) pose a public health problem because they are associated with high blood pressure. Underweight disturb endothelial function and, hence, the vascular tone is associated with BP (Ho, 2009). Subsequently, they lead to various cardiovascular risk factors like metabolic syndrome, type 2 diabetes, abnormal vascular wall thickness, endothelial dysfunction, left ventricular hypertrophy, high lifetime risk of hypertension, coronary heart diseases, stroke, respiratory problem and some cancers. (Cameron and Demerath, 2002; Kemper, 2004). Therefore, there is a need to diagnose malnutrition in Ellisras rural areas of South Africa in order to be able to prevent and control these factors that cause it.

2.2.1. MALNUTRITION IN AFRICA

Obesity is one of the risk factors of CVD that has a high prevalence of morbidity and mortality especially in developing countries. The prevalence of obesity and overweight in North African countries like Egypt, Tunisia, Algeria, Libya and Sudan for both rural and urban ranged from 1.3-47.8% (Toselli et al., 2014). West African countries (Cameroon, Ghana, and Nigeria) showed low prevalence of obesity (10%) due to low socio economic status (Abubakari et al., 2008). However, the prevalence of obesity in sub Southern African ranged from 0.4% to 43% (Dalal et al., 2011) and is closer to Northern African population. These prevalence of obesity in adults across the African continent may increase at a higher rate, due to the development of lifestyle changes, an increase in socio economic status and the influx of the population in the urban areas (Monyeki et al., 2000)

Underweight or thinness is directly associated with weak immune systems in the body, causing a lot of different diseases that will eventually lead to death (Black et al., 2003). In Africa the prevalence of underweight in adults is lowering every year as compared to obesity. However, in children it is dramatically increasing due to lack of food nutrients or unhealthy diets in some parts of Africa. This may be caused by the low socio-economic status especially in rural areas across the continent of Africa. Contrary, many studies have reported that the prevalence of obesity and overweight is increasing mostly in developed and developing countries (Prentice, 2006; Bhurosy and Jeewon, 2014).

Many prospective studies reported that overweight or obesity and underweight begin at an early age of life which is directly associated with obesity and underweight in adulthood (Chu et al., 1998; Parsons et al., 1999; Armstrong et al., 2003). There is a need for intervention to diagnose and manage children and adolescents with such conditions in order to lower their health risk factors in adulthood.

2.2.2 MALNUTRITION IN SOUTH AFRICA

South Africa, like all other developing countries, is undergoing epidemiological transitions due to urbanization. Puoane et al. (2002) reported that the prevalence of overweight or obesity among South Africans was 29.2% (≥ 25kg/m^2) and 9.2% had abdominal obesity (WHR ≥ 10) for men. On the other hand 56.6% women were overweight or obese and 42% had abdominal obesity (WHR ≥ 0.85). The prevalence of undernutrition was 12.2% among men and 5.6% for women. Monyeki et al. (2008) reported that the prevalence of thinness (severe, moderate, and mild) ranged from 7.1% to 53.7% for preschool children and from 8.0% to 47.6% for primary school children using BMI cut off points for thinness (Cole at al.,2007).

Children and adolescents obesity increases at a high rate and has reached an epidemic proportion where 1 out of 5 children and adolescents have obesity in developing countries like South Africa (Wang and Lobstein, 2006; Van der Merwe, 2012). The prevalence of overweight and obesity was 13.5% for South African children aged 6-14 years (Shisana et al., 2014). This is lower compared to other countries like Mexico, Brazil and Argentina (Mchiza, 2013). However, there is a need to investigate the prevalence of obesity in rural South African children due to the urbanization which is associated with an increase in obesity. The prevalence of underweight in children and adolescents as indicated by weight and age was 9.0% in South Africa. Boys had high significant prevalence of underweight than girls. Provincial prevalence of underweight was high in Northern Cape (14.3%), North West (14.2%), Limpopo (12.1%) and the lowest were reported in Western Cape (6.6%) (Reddy et al., 2003).

Monyeki et al. (2006), reported that overweight ranged from 1.1% to 2.9% for boys and 0.6% to 4.6% for girls in Ellisras rural areas.

2.2.3. DIAGNOSES OF MALNUTRITION

There are different methods of measuring malnutrition. They are laboratory and anthropometric techniques.

2.2.3.1. LABORATORY TECHNIQUES

Laboratory techniques like ultrasound, densitometry and dual energy x-ray are accurate enough to be used to assess malnutrition and are regarded as golden standards (Plowman and Smith, 2011).

- Ultrasound - measures malnutrition through scanning of visceral and subcutaneous fat in the body.
- Densitometry - measures malnutrition through calculation of bone density.
- Dual energy x - ray absorptiometry- measures malnutrition through scanning the whole body.

However, they are expensive, time consuming, could not be used in populations' studies and require sensitive instruments which can only be operated by highly trained technician (Roche et al., 1996).

2.2.3.2. ANTHROPOMETRICS TECHNIQUES

Several well-known anthropometric indicators that are in use to diagnose malnutrition (underweight and overweight or obesity) and growth proportions are waist circumference (WC), hip circumference (HC), body mass index (BMI), neck circumference (NC), mid upper arm circumference (MUAC), skinfolds and Components of height (height (SH) and SH to height ratio (SH/H) (De Almeida et al., 2003; Plowman and Smith, 2011; Hingorjo et al., 2012).These indicators are less expensive, reliable, valid, easy to use and could be used in population studies (Monyeki et al., 2008). However, the cut off points for malnutrition differ across the continents. Therefore, there is a need to establish the cut off points for malnutrition specifically in South African rural areas.

2.2.3.2.1. THE USE OF BODY MASS INDEX CUT OFF POINTS

Body mass index (BMI) is a ratio of the total body weight to height. Several ratios have been proposed, but the one used most frequently is weight (in kg) divided by height (in M) squared [weight ÷ $height^2$] (Plowman and Smith, 2011). The cut off points of BMI for malnutrition in children aged 2-18 years are specified by Cole et al. (2000) and (2007). Roberts et al. (2012) used cut off points to determine the prevalence of malnutrition in Canadian children aged 5-17 years. In South Africa, Monyeki et al. (2006) and Makgae et al. (2007) used only cut off points for overweight in Ellirsas children aged 6-13 years. Recently, van Den Ende et al. (2014) used both overweight and underweight for Ellisras children aged 6-12 years. Though, the interpretation of BMI results is difficult, as it reflects relative leg length, body frame size, and fat free mass in addition to fatness. Consequently, two (2) persons with the same amount of body fat can have quite different BMI values. Therefore, it means BMI gives no indication of fat distribution (Luis et al., 1999). Despite the potential problems with the use of BMI, these cut off points are the most suitable to use with samples of children in comparative studies of the prevalence of thinness rather than as references or standards for current or recommended BMI by age and sex (Cameron, 2007). Based on international BMI cut off points, other anthropometrics (Neck circumference and mid upper arm circumference) cut off points are yet to be established in rural South African children.

2.2.3.2.2. THE USE OF MID UPPER ARM CIRCUMFERENCE INDICES

Mid-upper arm circumference (MUAC) indicator has been proposed to measure central adiposity than BMI (Mazıcıoğlu et al., 2010). It has been reported that MUAC was significantly associated with waist circumference (Lu et al., 2014).

Advantages of Mid-Upper Arm Circumference (MUAC) screening (Briend, 2012).

- It is simple and cheap. It can be used by service providers at different contact points without greatly increasing their workload and it can be effectively used by community-based people for active case finding.

- It is more sensitive. MUAC is a better indicator of mortality risk associated more with malnutrition than Weight-for-Height. It is therefore a better measure to identify children mostly in need of treatment.

- It is less prone to mistakes. Comparative studies have shown that MUAC is subject to fewer errors than Weight-for-Height (Myatt et al., 2006).

- It increases the link with the beneficiary community. MUAC screening allows service providers from peripheral health units and from the community to refer children with acute malnutrition to therapeutic or supplementary feeding programs. The MUAC colour coding is easy to understand for the child's care-taker.

De Almeida et al. (2003) and Mazıcıoğlu et al. (2010) suggested that MUAC can be used as alternative method for obesity screening in preschool children aged 6-17 years. Age and gender specific MUAC cut offs have been introduced for children in two countries, Brazil and Turkey (De Almeida et al., 2003; Mazicioglu et al., 2010). However, no study was reported among South African children using BMI international cut off points and MUAC con-currently on the same population.

2.2.3.2.3. THE USE OF WAIST CIRCUMFERENCE INDICES

Waist circumference (WC) is one of the mostly used anthropometrics indicators for central obesity (where visceral adipose tissue is stored). WC cut off points for central obesity has been reported from different countries, for example in American (102 cm for men and 88 cm for women), Europeans (94 cm for men and 80 cm for women) and South Africans, specifically Zulus (86 cm for men and 92 cm for women) (Balkau et al., 1999; Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults, 2001; Motala et al., 2011). Recently, WHO (2000) reported that WC between 80.0–87.9 cm in women and 94.0–101.9 cm in men correspond with >25 BMI which is overweight in Caucasian populations. These WC cut off points for adults have been used in many studies from urban and rural areas of Africa (Murphy et al., 2013).

In children, WHO (1998) defined WC>80 cm as an abdominal obesity. Taylor et al. (2000) introduced WC cut off points for central adiposity by age and gender for children and adolescents aged 3-19 years. These cut off points for children have been used by Bergmann et al. (2010) to categorise school children with obesity. On the other hand, children with a WC greater than the 90th percentile are more likely to be overweight/obese than children with a WC that is less than or equal to the 90th percentile (Maffeis et al., 2001). Monyeki et al. (2008) used this percentile cut off to diagnose Ellisras rural children 7-13 years with overweight or obesity.

2.2.3.2.4. THE USE OF SKINFOLDS INDICES

Skinfolds or fat folds can be defined as the double thickness of skin, plus the adipose tissue between the parallel layers of the skin. It is another anthropometrics indicator that measures the distribution pattern of subcutaneous adipose fat (Tanner and Whitehouse, 1975). It has been reported that subcutaneous tissues are associated with total body fat. Skinfolds thickness values can be used to estimate percentages of total body fat (%BF) (Davidson et al., 2011).

Advantage of skinfolds (Wells and Fewtrel, 2006; Amaral et al., 2011).

- The skinfold calipers are not overly expensive.
- They does not require sophisticated equipment.
- They are portable to use.
- They are fast and can be sued in larger population.

In children and adolescents the most common sites to assess the adiposity are triceps, biceps, subscapular, and suprailiac skinfold thicknes (Klimek-Piotrowska et al., 2015).

Gaskin and Walker (2003) used the sum of skinfolds to calculate the %BF and categorise Jamaican children with high body fat. Moreover, Monyeki et al. (2008) used the sum of skinfolds (Subscapular, Suprailiac, Biceps and triceps) to diagnose rural

South African children with obesity. However, skinfolds thickness had been reported to measure the total body fat or the subcutaneous fats not central adiposity which is associated with CVDs. Furthermore, central adiposity is mostly measured by NC and MUAC among the population (Tanner and Whitehouse, 1975; Ben-Noun et al., 2001; Mazıcıoğlu et al., 2010).

2.2.3.2.5. THE USE OF NECK CIRCUMFERENCE

Neck circumference (NC) is an anthropometric variable that measures the fat distribution on the upper arm and onset of central obesity (Ben-Noun et al., 2001]. It is also reported that NC, as another predictor of visceral obesity, is more significantly associated with insulin resistance (IR) and diabetes 2 mellitus than WC in the European population (Yang et al., 2010; Zhou et al., 2013). Moreover, NC measurements had been shown to be a simple and time-saving screening measure to identify malnutrition.

Recently, many studies have introduced the NC cut off points for overweight and obesity in adults from different countries (Yang et al., 2010; Hingorjo et al., 2012). However, NC cut-off points for overweight in children aged 5 – 18 years in developed countries were established using BMI values (Nafiu et al., 2014). Therefore, the use of this NC with the international BMI cut-off points are yet to be used con-currently in rural South African children, in determining true positive and negative value screening diagnosis.

2.2.3.2.6. THE USE OF HEIGHT AND WEIGHT INDICES

Height and weight are the anthropometric indices that can be easily obtained in lager populations which are the measures of body size. Moreover, height and weight are mostly used to diagnose or assess malnutrition in children. Height, weight and age can be expressed as height for age (HAZ), weight for age (WAZ) and weight to height (WHZ), Z-scores or percent of median (Monyeki et al., 2000). The following equation shows how to calculate Z-score:

$z = (X - \mu) / \sigma$ (Kreyszig, 1979).

Where:

μ is the mean of the reference population.

σ is the standard deviation of reference population

X is the score of individual subject in the study population

The absolute value of z represents the distance between the score of the study and the mean of the reference population in units of the standard deviation of the reference population. The following points show the interpretation of Z- scores (Dibley et al., 1987; Chubb and Simpson, 2012):

A z-score less than 0 represents score less than the mean.

A z-score greater than 0 represents score greater than the mean.

A z-score equal to 0 represents score equal to the mean.

A z-score equal to 1 represents score that is 1 standard deviation greater than the mean; a z-score equal to 2, 2 standard deviations greater than the mean.

A z-score equal to -1 represents score that is 1 standard deviation less than the mean; a z-score equal to -2, 2 standard deviations less than the mean.

If the number of scores in the set is large, about 68% of the scores have a z-score between -1 and 1; about 95% have a z-score between -2 and 2; and about 99% have a z-score between -3 and 3.

2.2.3.2.6.1. HEIGHT TO AGE Z SCORE

Low height-for-age: Stunted growth reflects a process of failure to reach linear growth potential as a result of suboptimal health and/or nutritional conditions (Dibley et al., 1987; De Onis, 2006).

2.2.3.2.6.2. WEIGHT TO AGE Z SCORES

Low weight-for-age: Weight-for-age reflects body mass relative to chronological age. It is influenced by both the height of the child (height-for-age) and his or her weight (weight-for-height), and its composite nature makes interpretation complex (De Onis, 2006; Oldewage-Theron et al., 2011).

2.2.3.2.6.2. WEIGHT TO HEIGHT Z SCORE

Low weight-for-height: Wasting or thinness indicates in most cases a recent and severe process of weight loss, which is often associated with acute starvation and/or severe disease. However, wasting may also be the result of a chronic unfavourable condition (De Onis, 2006; Oldewage-Theron et al., 2011).

High weight-for-height: "Overweight" is the preferred term for describing high weight-for-height. Even though there is a strong correlation between high weight-for-height and obesity as measured by adiposity, greater lean body mass can also contribute to high weight-for-height (WHO, 1979; De Onis, 2006).

Many studies used the above Z scores to determine the prevalence of malnutrition. Oldewage-Theron et al. (2011) categorized primary school children in the Vaal region of South Africa into underweight and obesity. Monyeki et al. (2000) reported the net results of poor nutritional environment in which these Ellisras children live there is an increase in prevalence of malnutrition (HAZ, WAZ, WHZ). Moreover, mean heights, weights and BMI were less than the reference 5^{th} centile by 10 years of age of the reference population.

2.3 COMPONENTS OF HEIGHTS INDICES

Components of heights are sitting height (SH), SH to height ratio (SH/H) and leg length. These components height are used to represent growth proportion in children and adults. Consequently, high SH/H indicates relatively shorter legs for total height and low SH/H indicates relatively long legs for total height (Fredriks et al., 2005). It is well known that sitting height was used to represent trunk length in practice. Variations in leg length and the changing of the upper/lower body segment ratio during childhood could potentially mean that sitting height would be more closely associated with adiposity variables not dependent on height (Brannsether et al., 2014). Most studies reported that children and adolescents SH, SH/H and height increase proportionally with age by gender from developed countries (Fredriks et al., 2005; Bogin and Varela-Silva, 2010). However, in a rural setting few studies have been conducted to determine the components of heights among South African children.

2.4. BLOOD PRESSURE

Blood pressure (BP) is the pressure exerted by the blood against the wall of the vessels in the body. Mean arterial blood pressure (MAP) is the BP that is monitored and regulated because MAP is the main driving force that delivers blood to the organs in the body (Nobrega et al., 2014). Baroreceptor reflex (short term) and renin angiotensin and aldosterone system (long term) are the main regulatory mechanisms of MAP (Sherwood, 2010).This mechanisms will be outlined in details in 2.4.1 and 2.4.2

2.4.1. SUMMARY OF BARORECEPTOR FLEXES MECHANISM

If MAP is raising above normal, the baroreceptors (carotid sinus and aortic arch) will propagates the signal (information) to the cardiovascular centre in the brain via afferent neuron (Sherwood, 2010). The cardiovascular centre respond by activating the parasympathetic activity via efferent neuron which will results in decreasing MAP to normal (see figure 1(a)).

If MAP is decreasing below normal, the baroreceptors will propagates the signal to the cardiovascular centre in the brain via afferent neuron. The cardiovascular respond by activating sympathetic activity which will compensate drop in MAP.

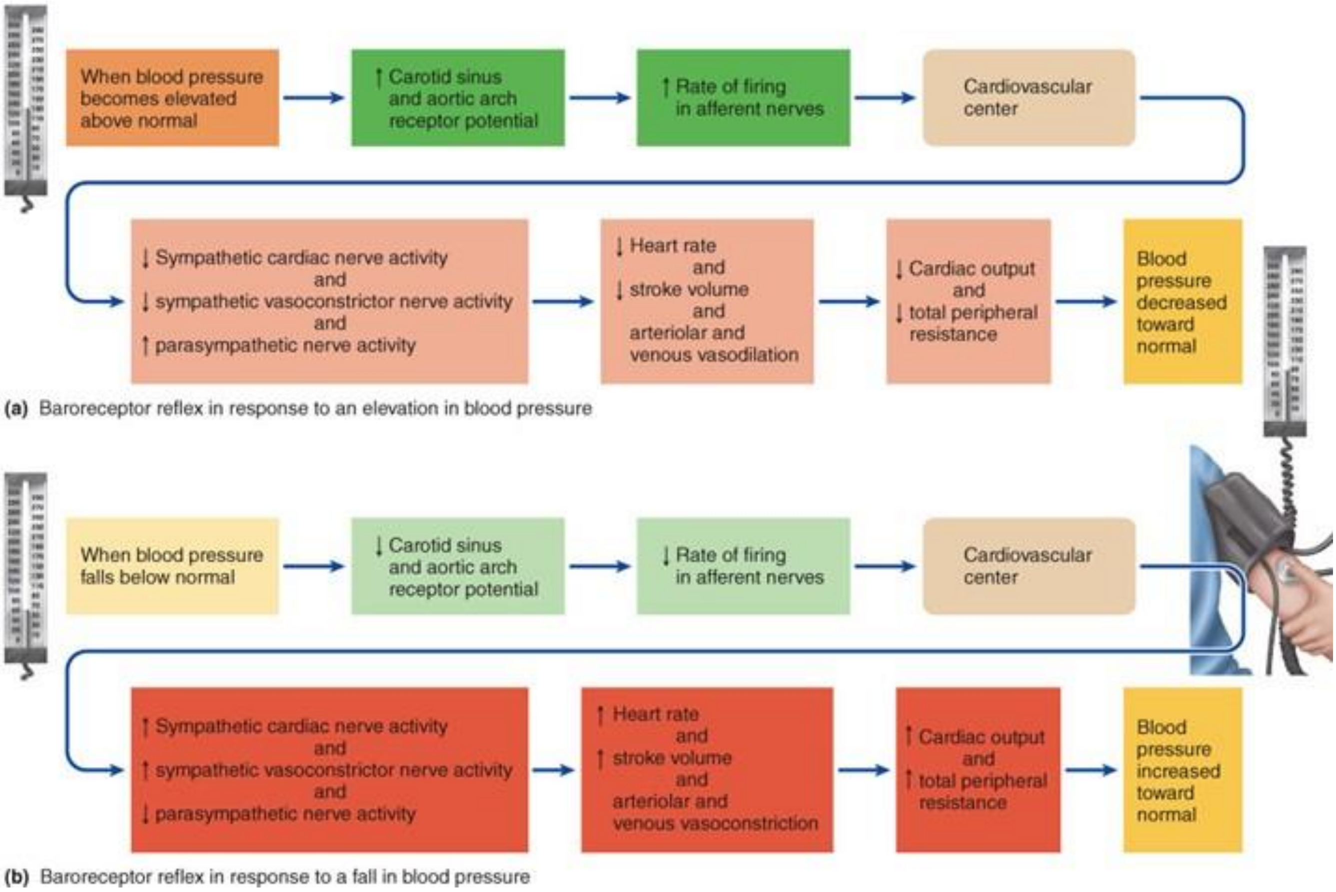

Figure 1: Baroreceptor reflexes to restore BP to normal (Sherwood, 2010).

2.4.2. SUMMARY OF RENNIN-ANGIOTENSIN-ALDOSTERONE SYSTEM

Rennin angiotensin aldosterone system (RAAS) is activated in response to low BP, Sodium chloride (NaCl) and extracellular fluid (ECF), then hormone renin will be secreted from juxta-glomerular apparatus into the blood stream to activate angiotensinogen to angiotensin I. On passing the lung angiotensin I will be converted to angiotensin II by Angiotensin converting enzyme (see figure 1(b) (Yee et al., 2010, Sherwood, 2010). Therefore angiotensin II performs many functions such as the following:

- Stimulates the secretion of hormone (aldosterone) from adrenal cortex which will increase reabsorption of Na+ in the kidney.
- Stimulates the thirst which will result in consumption of fluid
- Stimulates the secretion of vasopressin or antidiuretic hormone which will result in reabsorption of water in the kidney.

- Stimulates the arterial vasoconstriction which will result in increase in peripheral resistance.

All of these functions of angiotensin II will compensate low BP, NaCl and ECF in the body to maintain homeostasis.

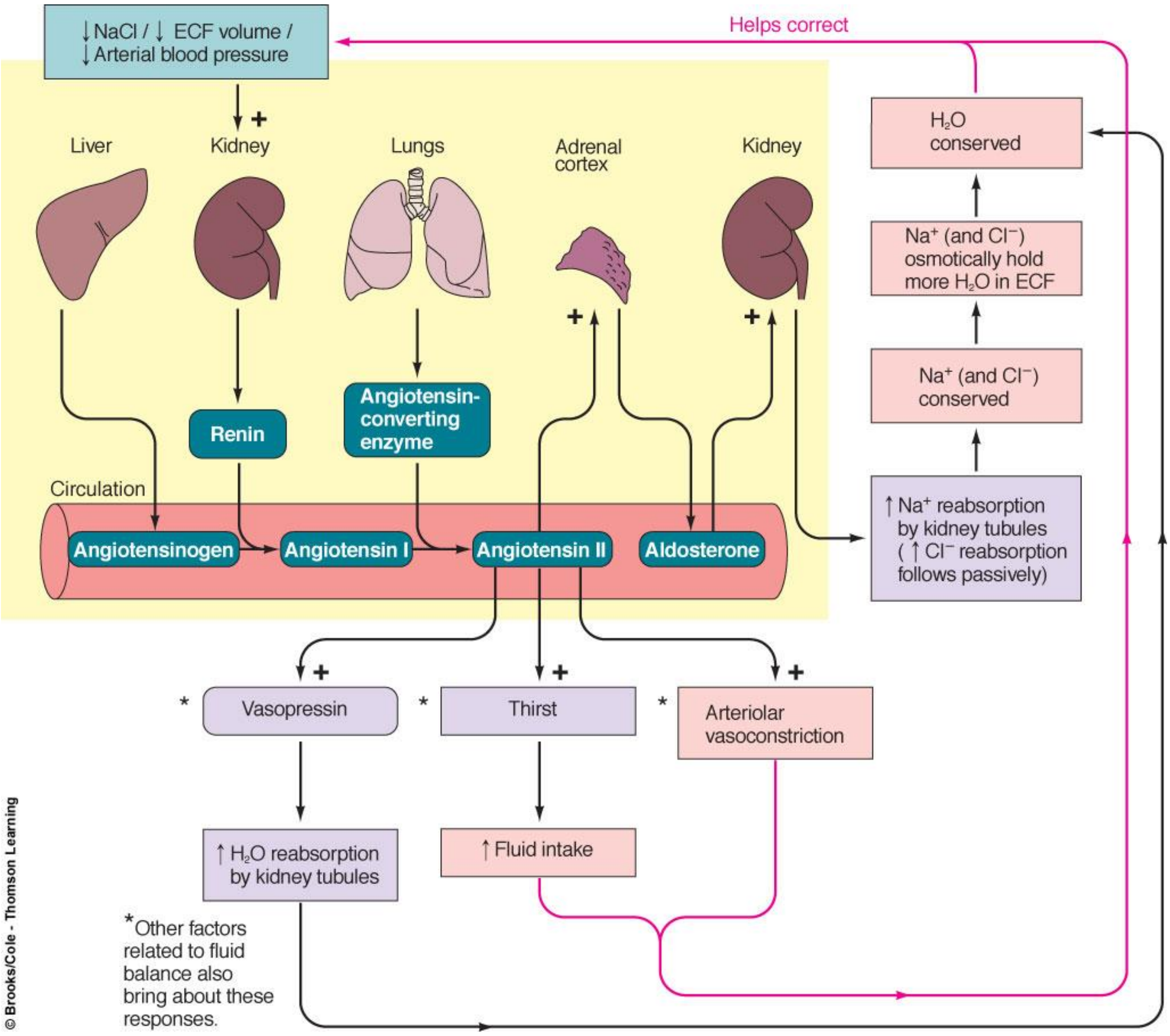

Figure 2: Renin-angiotensin –aldosterone system (RAAS) (Sherwood, 2007).

2.5. HYPERTENSION

If the BP regulatory mechanism above (2.4.1 and 2.4.2) does not function well it will result in hypertension and hypotension. Hypertension can be classified as primary (essential) or secondary hypertension depending on the cause.

2.5.1. ESSENTIAL OR PRIMARY HYPERTENSION

Essential, primary or idiopathic hypertension is defined as high BP in which the causes are unknown. Essential hypertension accounts about 90%-95% of hypertension cases (Poulter et al, 2015). However, there are potential causes of primary hypertension currently being reported (Carretero and Oparil, 2000).

- Excessive salt intake
- Insulin resistance
- Obesity
- Endogenous digitalis like substances
- Excess of vasopressin
- sedentary lifestyle
- Plasma membrane abnormalities such as defective Na^+ - K^+ pumps

2.5.2. SECONDARY HYPERTENSION

The secondary hypertension account for the remaining 5% - 10% of hypertension cases (Poulter et al, 2015). The causes of secondary hypertension are known because it is caused by other medical conditions that affect the following (Ker, 2011):

- Endocrine system and it is called Endocrine hypertension
- Kidney and it is called Renal hypertension
- Nervous system and it is called Neurogenic hypertension

2.5.3. THE USE OF CUT OFF POINTS FOR HYPERTENSION

Hypertension can be diagnosed using the general cut-off points of above 140mm Hg SBP and above 90 mmHg DBP (>140 mmHg / >90 mmHg) for adults (> 18 years) (Poulter et al, 2015). These cut-off values have been supported by The Joint National Committee on Detection, Evaluation, Treatment of High Blood pressure (1997) and Guidelines Subcommittee (1999). It might differ from country to country and change over a period of time. In South Africa, the Hypertension Society of Southern Africa (1995) defined hypertension as equal as or greater than 160 / 95 mmHg.

In children, The Task Force on Blood Pressure Control in Children, commissioned by the National Heart, Lung, and Blood Institute (NHLBI) of the National Institutes of Health (NIH), developed standards for BP by using the results of 11 surveys of more than 83,000 person-visits of infants and children. In accordance with the recommendations of the Task Force, BP is considered normal while the SBP and DBP values are less than the 90th percentile for the child's age, sex, and height were above 90^{th} percentile is considered as hypertension (National High Blood Pressure Education Program working group on hypertension control in children and adolescents, 2004). These cut off points are being used to determine the prevalence of hypertension or the status of blood pressure in paediatrics populations. For Example, Makgae et al. (2007) also used this cut off points to determine rural South African children with hypertension.

Therefore, these cut off points are to be used to diagnose Ellisras rural children with hypertension.

2.5.4. HYPERTENSION IN AFRICA

Hypertension is one of the medical conditions and risk factors for cardiovascular diseases (CVD) that are associated with the prevalence of morbidity and mortality from CVD (WHO, 2005). Moreover, African Union reported that hypertension is the second greatest health challenge after HIV/AIDS in the African continent (WHO Regional Office for Africa, 2006). The prevalence of abnormal high BP (hypertension) across the continent Africa differs according to geographical areas where Northern Africa was higher (33.3%) than sub-Saharan Africa (27.8%) whereas the Eastern, Central and western Africa were 26.8%, 21.1%, 27.3% respectively (Adeloye and Basquill, 2014). However in some parts of Sub Saharan Africa, the prevalence of South Africa may be increased nowadays due to the population growth and ageing, rising urbanization, mass migration from rural to urban areas, and an increased uptake of western lifestyles including tobacco and alcohol consumption (Opie and Seedat 2005; de-Graft et al., 2010).

2.5.5. HYPERTENSION IN SOUTH AFRICA

The overall prevalence of hypertension in South Africa was 21% using >140/>90 mmHg cut-off points, while 11% for men and 14% women were using 160/95mmHg cut-off points (Steyn et al., 2001). Recently, Peltzer and Phaswana-Mafuya (2013) reported the prevalence of hypertension to be 77.3% (men 74.4%, women 79.6%) from South Africa Study of Global Ageing and Adults' Health (SAGE) in 2008.

In South African children, the prevalence of hypertension was 12% for males and 21% for females due to high adiposity in female than males (Schutte et al., 2003). Recently, Kagura et al. (2015) found that the prevalence of hypertension ranged from 8.4% to 24% in children aged 5-18 years old. Furthermore, Makgae et al. (2007) reported that prevalence of hypertension ranged from 1 to 5.8% in boys and 3.4–11.4% in girls aged 6-13 years in Ellisras rural areas, South Africa

2.6. RELATIONSHIP OF DIFFERENT ANTHROPOMETRIC INDICATORS TO BLOOD PRESSURE

2.6.1. NECK CIRCUMFERENCE AND BLOOD PRESSURE

High BP is an established risk factor for cardiovascular and circulatory diseases (e.g. ischemic heart disease, stroke, or hypertensive heart disease) (Lim et al., 2012), and is considered to be the leading cause of death worldwide (responsible for 13 % of deaths globally) (Alwan, 2011). Ben and Laor (2004) found that changes in SBP and DBP correlate positively with change in NC in adults. Alfie et al. (2012) also reported that the association between neck circumference and high blood pressure was significant with normal waist circumference. Moreover, in children aged 6-18 years wide NC and high BMI were associated significantly with high rates of elevated blood pressure (Nafiu et al., 2014). Recently, Kuciene et al. (2015) reported that NC was significantly associated with high BP in Lithuanian children and adolescents aged 12 to 15 years. However, no study was done to investigate the association between BP and NC in South African children.

2.6.2. MID UPPER ARM CIRCUMFERENCE AND BLOOD PRESSURE

Mid-upper arm circumference (MUAC) has been commonly used in the assessment of nutritional status and It has been associated with BP. Kapoor et al. (2012) found that MUAC had a strong relationship with high blood pressure in Indian adults. On the other hand, Bassaroe et al. (2013) also reported that MAUC had a significant relationship with SBP but not DBP in Sardinian children aged 11-14 years. However, in rural South African children little is known about these relationships between BP and MUAC.

2.7. COMPONENTS OF HEIGHTS AND BLOOD PRESSURE

A number of studies have reported significant association between BP and body size while greater height was associated with BP in children and adolescents (Lauer et al., 1984; Regnault et al., 2014; Zhang et al., 2015).According to Marcato et al. (2014) SH not SH/H was significantly associated with BP in Brazilian children. Recently, Dong et al. (2016) maintain that SH was associated with BP in Chinese children and adolescents. However, no studies have been done to assess whether height, SH, SH/H can predict high BP in rural South African children to date.

2.8. RECEIVER OPERATING CHARACTERISTIC

In diagnostic test with dichotomous outcome (positive/negative test results), the conventional approach of diagnostic test evaluation uses sensitivity and specificity as measures of accuracy of test in comparison with gold standard status (Swets, 1979). Receiver operating characteristic (ROC) curve is a statistical graph or medical diagnostic test that plots Sensitivity versus 1- specificity and illustrates the area under curve (AUC).

2.8.1. SENSITIVITY

- The sensitivity of a diagnostic test is the proportion of patients for whom the outcome is positive that are correctly identified by the test.

2.8.2. SPECIFICITY

- The specificity is the proportion of patients whose outcome is negative and are correctly identified by the test.

2.8.3. AREA UNDER CURVE

Area under curve (AUC) has been reported with meaningful interpretations-

- Curve plays a central role in evaluating diagnostic ability of tests to discriminate the true state of subjects.
- To find the optimal cut off points or values
- To compare two alternative tasks when the task is performed on the same subject.

Many studies in clinical epidemiology have used the ROC to test the ability of the instrument or biomarkers and imaging test in classification of the diseased from the healthy person. For example, Taylor et al. (2000) used the ROC to the relative abilities of the anthropometric measures to correctly identify children with high trunk fat mass. Therefore, ROC curve will be used to investigate the ability of anthropometric indicators in identifying rural children with hypertension.

2.9. SUMMARY

Cardiovascular diseases (CVDs) are known as some of the silent killers in the world and are more common in adults. However prospective studies indicated that mostly CVDs begin at an early age and lead to adulthood. Malnutrition and hypertension (abnormal high blood pressure) are the major risk factors of CVDs and diabetes 2 mellitus. There is a need to diagnose these risk factors at an early age to enable and prevent or manage CVDs at adult age. Malnutrition in a large population can be diagnosed using anthropometric indicators because they are less expensive, reliable and valid. However, anthropometrics indicators cut off points for malnutrition differ across the world, so there is a need to establish new anthropometrics cut off points for malnutrition using international accepted body mass index (BMI) in rural South African children.

High blood pressure or hypertension in children is mostly diagnosed using the cut off points introduced by National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents in 2014. In South Africa few studies have been conducted to evaluate the prevalence of hypertension in South African children. Therefore, there is a need to investigate the prevalence of hypertension in rural South African children.

Many studies have reported that anthropometric indicators for malnutrition were associated with blood pressure in developed countries. Moreover, using ROC curve anthropometric indictors showed the ability to identify children who were hypertensive. However, little is known about the relationship between blood pressure and anthropometrics indicators.

2.10. REFERENCES

Abubakari AR, Lauder W, Agyemang C, Jones M, Kirk A, Bhopa RS. (2008). Prevalence and time trends in obesity among adult West African populations: a meta-analysis. *Obes Rev*, 9: 297–311.

Adeloye D, Basquill C. (2014). Estimating the prevalence and awareness rates of hypertension in Africa: a systematic analysis. *PLoS One*, 9:e104300.

Alfie J, Diaz M, Cufaro P, Rodríguez P, Fábreguez G, Magni R, Nucci S, Rodríguez MJ, Marín M. (2012). Relationship between neck circumference and hypertension in the National Hypertension Registry (the RENATA study). *Rev Argent Cardiol*, 80:1-6.

Alwan A. (2011). *Global status report on noncommunicable diseases 2010*. World Health Organization.

Amaral TF, Restivo MT, Guerra RS, Marques E, Chousal MF, Mota J. (2011). Accuracy of a digital skinfold system for measuring skinfold thickness and estimating body fat. *Br J Nutr*, 105:478-484.

Armstrong J, Dorosty A, Reilly J, Child H, Emmett P. (2003). Coexistence of social inequalities in undernutrition and obesity in preschool children: population based cross sectional study. *Arch Dis Child*, 88: 671–675.

Balkau B, Charles MA, Comment on the provisional report from the WHO consultation. (1999). European Group for the Study of Insulin Resistance (EGIR). *Diabet Med,* 16: 442–443.

Bassareo PP, Marras AR, Barbanti C, Mercuro G. (2013) Comparison between waist and mid-upper arm circumferences in influencing systolic blood pressure in adolescence: the SHARP (Sardinian Hypertensive Adolescent Research Programme) study. *JPNIM*, 2:e020207.

Ben-Noun LL, Laor A. (2004). Relationship between changes in neck circumference and changes in blood pressure*. Am J Hypertens*, 17:409-14.

Ben-Noun LL, Sohar E, Laor A. (2001). Neck circumference as a simple screening measure for identifying overweight and obese patients. *Obes Res*, 9:470–477.

Bergmann GG, Gaya A, Halpern R, Bergmann MLA, Rech RR, Constanzi CB, Alli LR. (2010). Waist circumference as screening instrument for cardiovascular disease risk factors in schoolchildren. *J Pediatr (Rio J),* 86:411-416.

Bhurosy T, Jeewon R. (2014). Overweight and Obesity Epidemic in Developing Countries: A Problem with Diet, Physical Activity, or Socioeconomic Status. *SCI WORLD J*, 2014: 1- 7.

Black RE, Morris SS, Bryce J. (2003). "Where and Why are 10 Million Children Dying Every Year?”. *Lancet*, 361: 2226–22234.

Bleich S, Cutler D, Murray C, Adams A. (2008). Why is the developed world obese?. *Annu Rev Public Health*, 29: 273–295.

Blössner M, de Onis M. (2005). *Malnutrition: quantifying the health impact at national and local levels*. Geneva: World Health Organization.

Bogin B, Varela-Silva MI. (2010). Leg length, body proportion, and health: a review with a note on beauty. *Int J Environ Res Public Health,* 7:1047-1075.

Brannsether B, Eide GE, Roelants M, Bjerknes R, Júlíusson PB. (2014). Interrelationships between anthropometric variables and overweight in childhood and adolescence. *Am J Hum Biol*, 26:502-510.

Briend A. Use of MUAC for severe acute malnutrition. (2012). CMAM forum: collaborating to improve the management of acute malnutrition worldwide.

Cameron N, Demerath EW. (2002). Critical periods in human growth and their relationship to diseases of aging*. Am J Phys Anthropol*, 35:159-1584.

Cameron N. (2007). Body mass index cut offs to define thinness in children and adolescents. *BMJ*, 335:166-167.

Carretero OA, Oparil S. (2000). Essential Hypertension Part I: Definition and Etiology. *Circulation*, 101:329-335.

Chu NF, Rimm EB, Wang DJ, Liou HS, Sheih SM. (1998). Clustering of cardiovascular disease risk factors among obese school children: the Taipei children heart study. *Am J of Clin Nutrtn,* 67:1141–1146.

Chubb H, Simpson JM. (2012). The use of Z-scores in paediatric cardiology. *Ann Pediatr Cardiol,* 5: 179–184.

Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. (2000). Establishing a standard definition for child overweight and obesity worldwide: International survey. *BMJ*, 320:1240-1243.

Cole TJ, Flegal KM, Nicholls D, Jackson AA. (2007). Body mass index cut - offs to define thinness in children and adolescents: International survey. *BMJ*, 335:194.

Dalal S, Beunza JJ, Volmink J, Adebamowo C, Bajunirwe F, Njelekela M, Mozaffarian D, Fawzi W, Willett W, Adami H, Holmes MD. (2011). Non-communicable diseases in sub-Saharan Africa: what we know now. *Int J Epidemiol*. 40:885-901.

Davidson LE, Wang J, Thornton JC, Kaleem Z, Silva-Palacios F, Pierson RN, Heymsfield SB, Gallagher D. (2011). Predicting Fat Percent by Skinfolds in Racial Groups: Durnin and Womersley Revisited. *Med Sci Sports Exerc*, 43: 542–549.

De Almeida CA, Del Ciampo LA, Ricco RG, Silva Jr SM, Naves RB, Pina JF. (2003) Assessment of mid-upper arm circumference as a method for obesity screening in preschool children. *J Pediatr*, 79:455-460.

De Onis M. (2006). *WHO child growth standards: length/height-for-age, weight-for-age, weight-for-length, weight-for-height and body mass index-for-age*. World Health Organization.

de-Graft Aikins A, Unwin N, Agyemang C, Allotey P, Campbell C, Arhinful D. (2010). Tackling Africa's chronic disease burden: from the local to the global. *Global Health*, 6:5. doi: 10.1186/1744-8603-6-5.

Dibley MJ, Staehling N, Nieburg P, Trowbridge FL. (1987). Interpretation of Z-score anthropometric indicators derived from the international growth reference. *Am J Clin Nutr*, 46: 749-762.

Dong B, Wan Z, Ma J. (2016). Leg to trunk ratio and the risk of hypertension in children and adolescents: a population-based study. *J Public Health*, 203: doi: 10.1093

Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults. (2001) Executive Summary of the Third Report of the National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III). *JAMA*, 285: 2486–2497.

Fredriks AM, Van Buuren S, Van Heel WJM, Dijkman-Neerincx RHM, Verloove-Vanhorick SP, Wit JM. (2005). Nationwide age references for sitting height, leg length, and sitting height/height ratio, and their diagnostic value for disproportionate growth disorders. *Arch Dis Child*, 90: 807- 812.

Gaskin PS, Walker SP. (2003). Obesity in a cohort of black Jamaican children as estimated by BMI and other indices of adiposity. *Eur J Clin Nutr*, 57: 420 – 426.

Guidelines Subcommittee. (1999). World Health Organization-International Society of Hypertension Guidelines for the Management of Hypertension. *J Hypertens*, 17:151-183.

Hingorjo MR, Qureshi MA, Mehdi A. (2012). Neck circumference as a useful marker of obesity: a comparison with body mass index and waist circumference. *J Pak Med Assoc,* 62:36-40.

Ho FT. (2009). Cardiovascular risk associated with obesity in children and adolescents. *Ann Acad Med*, 39: 56.

Hypertension Society of Southern Africa. (1995). Guidelines for the management of hypertension at primary health care level. *S Afr Med J*, 85:1321-1325.

Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure. (1997). The sixth report of the Joint National Committee on prevention, detection evaluation, and treatment of high blood pressure. *Arch Intern Med*, 157:2413- 2446.

Kagura J, Adair LS, Musa MG, Pettifor JM, Norris SA. (2015). Blood pressure tracking in urban black South African children: birth to twenty cohort. BMC *Pediatr*, 15:1.

Kapoor AK, Saluja K, Verma D, Kapoor S. (2012). Predictors of Hypertension among Adult Tribal Males of India. *IJTDH*, 2: 241-256.

Kemper HCG. (2004). *Amsterdam growth and health Longitudinal study: A 23 year follow up from teenagers to adult about lifestyle and health.* New York, Karger press, pp 1-20.

Ker JA. (2011). Secondary hypertension. *S Afr Fam Pract*, 53: 441-442.

Klimek-Piotrowska W, Koziej M, Hołda MK, Piątek K, Wszołek K, Tyszka A, Kmiotek E, Pliczko , Śliwińska A, Krauss K, Miszczyk M, Walocha J. (2015). Anthropometry and Body Composition of Adolescents in Cracow, Poland. *PLoS One.*10: e0122274.

Kreyszig E. (1979). *Advanced Engineering Mathematics* (Fourth ed.). Wiley. ISBN 0-471-02140-7.

Kuciene R, Dulskiene V, Medzioniene J. (2015). Association of neck circumference and high blood pressure in children and adolescents: a case-control study. *BMC Pediatr*, 15:127. doi: 10.1186/s12887-015-0444-2.

Lauer RM, Anderson AR, Beaglehole R, Burns TL. (1984). Factors related to tracking of blood pressure in children. U.S. National Center for Health Statistics Health Examination Surveys Cycles II and III. *Hypertension*, 6:307–314.

Lim SS, Vos T, Flaxman AD, Danaei G, Shibuya K, Adair-Rohani H. (2012). A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet*, 380:2224–2260.

Lu Q, Wang R, Lou DH, Ma CM, Liu XL, Yin FZ. (2014). Mid-upper-arm Circumference and Arm-to-height Ratio in Evaluation of Overweight and Obesity in Han Children. *Pediatr Neonatol*, 55: 14-19.

Luis BS, Scott BG, Pedro JT, Timothy GL. (1999). Receiver operating characteristic analysis of body mass index, triceps skinfold thickness and arm girth for obesity screening in children and adolescents. *Am J Clin Nutr*, 70:1090-1095.

Maffeis C, Angelo P, Alessandra G, Silvia P, Luciano T. (2001). Waist circumference and cardiovascular risk factors in pre pubertal children. *Obes Res*, 9: 179–187.

Makgae PJ, Monyeki KD, Brits SJ, Kemper HC, Mashita J. (2007). Somatotype and blood pressure of rural South African children aged 6-13 years: Ellisras longitudinal growth and health study. *Ann Hum Biol*, 34:240-251.

Marcato DG, Sampaio JD, Alves ERB, de Jesus JSA, Fuly JTB, Giovaninni NPB. (2014). Sitting-height measure are related to body mass index and blood pressure in children. *Arq Bras Endocrinol Metab*, 58:802-806.

Mazıcıoğlu MM, Hatipoğlu N, Oztürk A, Ciçek B, Ustünbaş HB, Kurtoğlu S. (2010). Waist circumference and mid-upper arm circumference in evaluation of obesity in children aged between 6 and 17 years. *J Clin Res Pediatr Endocrinol*, 2: 144-150.

Mchiza Z. (2013). Fighting childhood obesity. *S Afr J Clin Nutr*, 26:100-102.

Montagnese C, Nutile T, Marphatia AA, Grijalva-Eternod CS, Siervo M, Ciullo M. (2014). Body composition, leg length and blood pressure in rural Italian population; a test of the capacity-load model. *Nutr Metab Cardiovasc Dis*, 24: 1204 – 1212.

Monyeki KD, Cameron N, Getz B. (2000).Growth and nutritional status of rural South African children 3-10 years old: The Ellisras growth study. *Am J Hum Biol*, 12:42-49.

Monyeki KD, de Ridder JH, Steyn NP, Toriola AL, Kemper HCG, Nthangeni ME. (2002). Stability of somatotypes in 4–10 year-old rural South African girls. *Ann Hum Biol*, 29: 37–49.

Monyeki KD, Kemper HCG, Makgae PJ. (2006). The association of fat patterning with blood pressure in rural South African children: the Ellisras Longitudinal Growth and Health Study. *Int J Epidemiol*, 35: 114-120.

Monyeki KD, Kemper HCG, Makgae PJ. (2008). Relationship between fat patterns, physical fitness and blood pressure of rural South African children: Ellisras Longitudinal Growth and Health Study. *J Hum Hypertens*, 22: 311–319.

Motala AA, Esterhuizen T, Pirie FJ, Omar MA. (2011). The prevalence of metabolic syndrome and determination of the optimal waist circumference cutoff points in a rural South African community. *Diabetes Care*, 34:1032–1037.

Murphy GAV, Asiki G, Ekoru K, Nsubuga RN, Nakiyingi-Miiro J, Young EH, Seeley J, Sandhu MS, Kamali A. (2013). Sociodemographic distribution of non-communicable disease risk factors in rural Uganda: a cross-sectional study. *Int J Epidemiol*, 42:1740–1753.

Myatt M, Khara T, Collins S. (2006). A review of methods to detect cases of severely malnourished children in the community for their admission into community-based therapeutic care programs. *Food Nutr Bull,* 27:7-23.

Nafiu OO, Zepeda A, Curcio C, Prasad Y. (2014). Association of neck circumference and obesity status with elevated blood pressure in children. *J Hum Hypertens,* 28: 263-268.

National High Blood Pressure Education Program (NHBPEP) working group on hypertension control in children and adolescents. (1996). Update on the 1987 task force report on high blood pressure in children and adolescents: a working group report from the National High Blood Pressure Education Program. *Paediatrics*, 98: 649–658.

National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents.(2004).The fourth report on the diagnosis, evaluation, and treatment of high blood pressure in children and adolescents. *Paediatrics,* 114: 555–576.

Nobrega AC, O'Leary D, Silva BM, Marongiu E, Piepoli MF, Crisafulli A. (2014). Neural regulation of cardiovascular response to exercise: role of central command and peripheral afferents. *Biomed Res Int*, 2014:478965. doi: 10.1155/2014/478965.

Oldewage-Theron W, Napier C, Egal A. (2011). Dietary fat intake and nutritional status indicators of primary school children in a low-income informal settlement in the Vaal region. *S Afr J Clin Nutr*, 24:99-104.

Opie LH, Seedat YK. (2005). Hypertension in sub-Saharan African populations. *Circulation*, 112: 3562–3568.

Parsons TJ, Power C, Logan S, Summerbell CD. (1999). Childhood Predictors of Adult Obesity: A Systematic Review. *Int J Obes Relat Metab Disord*, 23:1–107.

Patrick K, Norman GJ, Calfas KJ, Sallis JF, Zabinski MF, Rupp J, Cella J . (2004). Diet, Physical Activity, and Sedentary Behaviors as Risk Factors for Overweight in Adolescence. *Arch Pediatr Adolesc Med,* 158:385-390.

Peltzer K, Phaswana-Mafuya N. (2013). Hypertension and associated factors in older adults in South Africa. *Cardiovasc J Afr*, 24:67-71.

Plowman SA, Smith DL. (2011). *Exercise physiology for health, fitness and performance*. 3rd ed. USA: Lippincott Williams and Wilkins: 189-203.

Poulter NR, Prabhakaran D, Caulfield M. (2015). Hypertension. *Lancet,* 386: 801–812.

Prentice AM. (2006). The emerging epidemic of obesity in developing countries. *Int J Epidemiol*, 35: 93–99.

Puoane T, Steyn K, Bradshaw D, Laubscher R, Fourie J, Lambert V, Mbananga N. (2002). Obesity in South Africa: The South African Demographic and Health Survey. *Obes Res*, 10:1038–1048.

Reddy SP, Panday S, Swart D, Jinabhai CC, Amosun SL, James S, Monyeki KD, Stevens G, Morejele N, Kambaran NS, Omardien RG and Van den Borne HW. (2003). *Umthenthe Uhlaba Usamila – The South African Youth Risk Behaviour Survey 2002*. Cape Town: South African Medical Research Council.

Regnault N, Kleinman KP, Rifas-Shiman SL, Lengenberg C, Lipshultz SE, Gillman MW. (2014). Componets of height and blood pressure in childhood. *Int J Epidemol*, 43: 149-159.

Roberts KC, Shields M, de Groh M, Aziz A, Gilbert J. (2012). Overweight and obesity in children and adolescents: Results from the 2009 to 2011 Canadian Health Measures Survey. *Health Reports*, 23: 37-41.

Roche AF, Lohman TG, Heymsfield SB. (1996). *Human Body Composition*. Champaign, IL: Human Kinetics.

Schutte AE, van Rooyen JM, Huisman HW, Kruger HS, Malan NT, De Ridder JH. (2003).Dietary risk markers that contribute to the aetiology of hypertension in black South African children: the THUSA BANA study. *J Hum Hypertens*, 17, 29–35.

Sherwood L. (2007). *Human physiology: from cells to systems*. 6th ed. Australia; United States: Brooks/Cole, Cengage Learning.

Sherwood L. (2010). *Human physiology: from cells to systems*. 7th ed. Australia; United States: Brooks/Cole, Cengage Learning.

Shisana O, Labadarios D, Rehle T, Simbayi L, Zuma K, Dhansay A, Reddy P, Parker W, Hoosain E, Naidoo P, Hongoro C, Mchiza Z, Steyn NP, Dwane N, Makoae M, Maluleke T, Ramlagan S, Zungu N, Evans MG, Jacobs L, Faber M, SANHANES-1 Team. (2014). *South African National Health and Nutrition Examination (NHANES-1)*. Cape Town: HSRC Press.

Sliwa K, Wilkinson D, Hansen C, Ntyintyane L, Tibazarwa K, Becker A, Stewart S. (2008). Spectrum of heart disease and risk factors in a black urban population in South Africa (the Heart of Soweto Study): a cohort study. *Lancet*, 371: 915-922.

Steyn K, Gaziano TA, Bradshaw D, Laubscher R, Fourie J. (2001). South African Demographic and Health Coordinating Team. Hypertension in South African adults: results from the Demographic and Health Survey, 1998. *J Hypertens,* 19:1717-25.

Swets JA. (1979). ROC analysis applied to the evaluation of medical imaging techniques. *Invest Radiol*, 14:109–121.

Tanner JM, Whitehouse RH. (1975). Revised standards for triceps and subscapular skinfolds in British children. *Arch Dis Child,* 50:142-145.

Taylor RW, Jones IE, Williams SM, Goulding A. (2000). Evaluation of waist circumference, waist-to-hip ratio, and the conicity index as screening tools for high trunk fat mass, as measured by dual-energy X-ray absorptiometry, in children aged 3-19 years. *Am J Clin Nutr*, 72:490-495.

Toselli S, Gualdi-Russo E, Boulos DNK, Anwar WA, Lakhoua C, Jaouadi I, Khyatti M, Kari Hemminki K. (2014). Prevalence of overweight and obesity in adults from North Africa. *Eur J Pub Health*, 24:31–39.

Twagirumukiza M, De Bacquerb D, Kips JG, de Backer G, Vander Stichele R, Van Bortel LM. (2011). Current and projected prevalence of arterial hypertension in sub-Saharan Africa by sex, age and habitat: an estimate from population studies. *J Hypertens*, 29: 1243-1252.

Van Den Ende C, Twisk JWR, Monyeki KD. (2004).The relationship between BMI and dietary intake of primary school children from a rural area of South Africa: The Ellisras Longitudinal Study. *Ann Hum Biol*, 26: 701-706.

Van der Merwe MT. (2012). Obesity in childhood and adolescence. *S Afr Med J,* 102:289.

Van Lenthe FJ, Kemper HCG, Van Mechelen W, Twisk JWR. (1996). Development and tracking of central patterns of subcutaneous fat in adolescence and adulthood: The Amsterdam Growth and Health Study. *J Epidemiol*, 25: 1162-1171.

Wang Y, Lobstein T. (2006). Worldwide trends in childhood overweight and obesity. *Int J Pediatr Obes,* 1:11-25.

Wells JCK, Fewtrel MS. (2006). Measuring body composition. *Arch Dis Child*, 91: 612–617.

WHO Regional Office for Africa. (2006). *The health of the people: the African regional health report (2006)*. Geneva: World Health Organization.

World Health Organization (2000). *Obesity: Preventing and Managing the Global Epidemic.* Geneva: WHO Technical report series No. 894.

WHO (2000). The Asia-Pacific perspective: redefining obesity and its treatment. Health Communications Australia: Melbourne.

World Health Organization. (1979). *Measurement of nutritional impact*. Geneva: World Health Organization.

World Health Organization. (1998). *Report of a WHO consultation on Obesity: preventing and managing the global epidemic*. Geneva: World Health Organization.

World Health Organization. (2000). International association for the study of obesity, international obesity task force. *The Asia-Pacific perspective: redefining obesity and its treatment*, pp.15-21.

World Health Organization. (2000). *Technical report series 894: Obesity: Preventing and managing the global epidemic.* Geneva: World Health Organization.

World Health Organization. (2005). *Preventing chronic diseases: a vital investment: WHO global report.*

Yang GR, Yuan SY, Fu HJ, Wan G, Zhu LX, Bu XL, Zhang JD, Du XP, Li YL, Ji Y, Gu XN, Li Y, Beijing Community Diabetes Study Group. (2010). Neck circumference positively related with central obesity, overweight, and metabolic syndrome in Chinese subjects with type 2 diabetes: Beijing Community Diabetes Study 4. *Diabetes Care*, 33:2465-2467.

Yang L, Samarasinghe YP, Kane P, Amiel SA, Aylwin SJ. (2010).Visceral adiposity is closely correlated with neck circumference and represents a significant indicator of insulin resistance in WHO grade III obesity. *Clin Endocrinol (Oxf),* 73:197–200.

Yee AH, Burns JD, Wijdicks EF. (2010). "Cerebral salt wasting: pathophysiology, diagnosis, and treatment". *Neurosurg Clin N Am,* 21: 339–352.

Zhang Y, Zhao J, Chu Z, Wang L. (2015).The association between components of height and blood pressure among children and adolescents in Shandong, China. *Int J Cardiol*, 182:18-19.

Zhou JY, Ge H, Zhuet MF. (2013). Neck circumference as an independent predictive contributor to cardio-metabolic syndrome. *Cardiovasc Diabetol,* 12:76. doi: 10.1186/1475-2840-12-76.

CHAPTER 3

MATERIALS AND METHODS

3.1. GEOGRAPHICAL AREA

Ellisras, now known as Lephalale, is a deep rural area situated within the north-western area of Limpopo Province, South Africa. The population is ~50 000 people from formal residing in 42 rural settlements (Sidiropoulos et al., 1996). These villages are situated ~70 km from the town of Ellisras (23^0 40S 27^0 44W) adjacent to the Botswana border.

The Iscor coal mine and Matimba electricity power station are the major sources of employment for many residents in Ellisras, whereas the remaining workforce is involved in subsistence farming and cattle rearing, while a minority is in education and the civil services. Unemployment, poverty, and low life expectancy play a significant role in rural South African population, and Ellisras rural area is no exception (Bradshaw & Steyn, 2001; Statistics South Africa, 2002).

3.2. SAMPLE

The Ellisras Longitudinal Study (ELS) initially followed a cluster sampling method. In brief, the study was undertaken at 22 schools (10 preschools and 12 primary schools) randomly selected from 68 schools within the Ellisras area. Birth records were obtained from the principals of each school. Only those records that were verified against health clinic records were used to determine the age of each potential participant. Each of the 22 selected schools was assigned a grade with the expectation that most of the children in a particular age category (3–10 years) would be found in that grade.

BP parameters and anthropometric measurements of the ELS participants were performed on 1029 boys and 932 girls (n = 1961), aged 5–12 years. The Ethics Committee of the University of the North, now known as University of Limpopo, granted ethical approval prior to the study, and the parents or guardians were provided with written informed consent (MREC /P/204/2013:IR).

3.3. SAMPLING AND DATA COLLECTION

Using STATA, the sample size required to test for the period of measurement effect was calculated based on a Power of 80% and a two tailed significance level of 5%, prevalence of obesity 0.7%, two groups (boys and girls) of 40 participants were needed (Monyeki et al., 2008; Makkes et al., 2011). A total of 80 children (40 males and 40 females) aged 5 - 12 years were recruited and measured in the Ellisras rural area during the period November 2015. Similar procedures for the training of field workers for anthropometric and BP measurements were carried out under the supervision of the ELS principal investigator. The data form for the relevant variables in the current study is attached (Appendix A).

3.4. ANTHROPOMETRY

The children were anthropometrically measured using the International Society for the Advancement of Kinathropometry (ISAK) (Norton and Olds, 1996). Weight was measured with an electronic scale to the nearest 0.1 kg, and a Martin anthropometer was used to measure heights to the nearest 0.1 cm. Sitting height (SH) was measured by bringing the horizontal bar of Martin anthropometer into the most superior midline of the head while the child was sitting in erect position on a flat stool or box. Leg length (LL) is the height from the floor to the landmark trochanterion and it was measured with the subject‘s feet standing together and the lateral aspect of their right leg against the box. The base of the caliper was placed flush on top of the box and the caliper was oriented vertically upwards with the moving arm positioned at the marked trochanterion site (Norton and Olds, 1996). A flexible steel tape was used to measure the neck circumference (NC) and the mid-upper arm circumference (MUAC) to the nearest 0.1 cm. Body mass index (BMI) was defined as weight (kg) per height squared (m^2)

3.5. BLOOD PRESSURE MEASUREMENTS

Using an electronic Micronta monitoring kit (Omron), at least three BP readings of systolic blood pressure (SBP) and diastolic blood pressure (DBP) were taken at an interval of five minutes apart after the child had been seated for 5 minutes or longer (Update on the 1987 Task Force Report on High Blood Pressure in Children and Adolescents: a working group report from the National High Blood Pressure Education Program, 1996; National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents, 2004). The bladder of the device contains an electronic infrasonic transducer that monitors the BP and pulse rate, displaying these con-currently on the screen.

Figure 3: Picture shows blood pressure measurements

This versatile instrument has been designed for research and clinical purposes. In a pilot study, conducted before the survey, a high correlation (r = 0.93) was found between the readings taken with the automated device and those taken with a conventional mercury sphygmomanometer.

3.6. QUALITY CONTROL

All training of anthropometric measurements was done in accordance with the standard procedures of the ISAK (Norton and Olds, 1996). Reliability and validity of anthropometric measurements were reported elsewhere (Monyeki et al., 2002). In brief, the absolute and relative values for intra- and inter-tester technical error of measurements (% TEM) for stature, ranged from 0.04-4.16 cm (0.2-5.01%) and circumference measurements ranged from 0.0-3.4 cm (0-4%) (Monyeki et al., 2002; 2008).

3.7. STATISTICAL ANALYSIS

3.7.1. PERIOD OF MEASUREMENT EFFECTS

Prior analysis, Student test was used to test significant ($P<0.01$) difference between measurements carried out in November 2015 and November 1999 for anthropometric indicators (NC, MUAC, Height, weight, SH and SH/H).

3.7.2. DESCRIPTIVE STATISTICS

Descriptive statistics was presented for component of heights, BMI, NC, MUAC and BP in the Ellisras rural children aged 5 to 12 years. The independent t-test was applied to test the significance level ($P < 0.05$) between sexes. All children were classified as overweight and obese according to Cole et al. (2000) cut off points. The international cut-off points for underweight (grade one, two, and three) by sex for exact ages were defined to pass through BMI of 16, 17, and 18 kg/m^2 were used (Cole et al., 2007; Cameron, 2007). Hypertension was defined as the occurrence of SBP and DBP levels greater than or equals to the 95th percentile of height and sex adjusted reference levels (National High Blood Pressure Education Program (NHBPEP) working group on hypertension control in children and adolescents, 2004). Components of heights (SH and SH/H) of Ellisras children were compared with NHANES (National Health and Nutrition Examination Survey) III reference population (Frisancho, 1990).

3.7.3. LINEAR REGRESSION

The linear regression models were used to assess the relationship between BP and anthropometric indicators for unadjusted and adjusted age and gender.

3.7.4. RECEIVER OPERATING CURVE (ROC) ANALYSIS

We assessed the ability of NC, MUAC, BMI and components of height to discriminate children with elevated BP. For this purpose, we produced sex-specific receiver operating characteristics (ROC) curves and used the corresponding area under curves (AUC) to determine the ability of each anthropometric indicator in identifying children with elevated BP. The ROC curve is a plot of true-positive rate (sensitivity) against the false-positive rate (1-specificity). A good test has ROC skewed to the upper left corner with AUC of 1, whereas an AUC of 0.5 means that the test performs no better than chance (Schisterman et al., 2001; Zhou at el., 2002). Sensitivity and specificity of NC and MUAC have been calculated at all possible cut-off points to find optimal cut off value. The optimal sensitivity and specificity were the values yielding maximum sums from the ROC curves (clinical significance of cut off was checked with the Youden index). Cut off values and the corresponding AUCs as well as positive predictive value (PPV) and negative predictive value (NPPV) of NC and MUAC for underweight were computed along age and gender.

3.7.5. STATISTICAL PACKAGE AND SIGNIFICANT LEVEL

All the statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS) version 23. The statistical significance was set at $P < 0.05$.

3.8. REFERENCES

Bradshaw D, Steyn K. (2001). *Poverty and Chronic Disease in South Africa: Technical Report*. Cape Town: Medical Research Council, pp 38–45.

Cameron N. (2007). Body mass index cut offs to define thinness in children and adolescents. *BMJ*, 335:166-167.

Cole TJ, Bellizzi MC, Flegal KM, Dietz WH (2000) Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ*, 320: 1240-1243.

Cole TJ, Flegal KM, Nicholls D, Jackson AA (2007) Body mass index cut offs to define thinness in children and adolescents: international survey. *BMJ*, 335: 194.

Frisancho AR. (1990). *Athropometric standards for the assessment of growth and nutriritinal status.* Ann Arbor: the University of Michigan Press.

Makkes S, Halberstadt J, Renders Cm, Bosmans JE, van der Baa-Slootweng OH, Seidell JC. (2011). Cost-effectiveness of intensive inpatient treatments for severely obese children and adolescents in the Nertherlans; a rondamized controlled trial (HELIOS). *BMC public health*, 11: 518.

Monyeki KD, Kemper HCG, Makgae PJ. (2008). Relationship between fat patterns, physical fitness and blood pressure of rural South African children: Ellisras Longitudinal Growth and Health Study. *J Hum Hypertens*, 22: 311–319.

Monyeki KD, Toriola AL, De Ridder JH, Kemper HC, Steyn NP, Nthangeni ME, Twisk JW, Van Lenthe FJ. (2002). Stability of somatotypes in 4 to 10 year-old rural South African girls. Ann Hum Biol, 29: 37-49.

National High Blood Pressure Education Program (NHBPEP) working group on hypertension control in children and adolescents. (1996). Update on the 1987 task force report on high blood pressure in children and adolescents: a working group report from the National High Blood Pressure Education Program. *Paediatrics*, 98: 649–658.

National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents. (2004).The fourth report on the diagnosis, evaluation, and treatment of high blood pressure in children and adolescents. *Paediatrics*, 114: 555–576.

Norton K, Olds T. (1996). *Anthropometrica*. Sydney: University of New South Wales Press: 396-410.

Schisterman EF, Faraggi D, Reiser B, Trevisan M. Statistical inference for the area under the receiver operating characteristic curve in the presence of random measurement error. (2001). *Am J Epidemiol* 154: 174–179

Sidiropoulos E, Jeffery A, Mackay S, Gallocher R, Forgey H, Chips C. (1996*). South Africa Survey 1995/1996*. Johannesburg: South African Institute of Race and Relations, pp. 234–360.

Statistics South Africa. (2002). *Cause of Death in South Africa 1997–2001: Advance Release of Records of Death*. Pretoria: Statistics South Africa, pp 18–42.

Zhou X-H, Obuchowski NA, McClish DK. (2002) *Statistical Methods in Diagnostic Medicine*. New York: Wiley-Interscience.

CHAPTER 4

RESULTS AND DISCUSSION

4.1. Results and discussion

4.2. References

4.1 RESULTS AND DISCUSSION

Table 1 showed the period of measurements effects between measurements taken in November 1999 and November 2015 for Ellisras rural children aged 5 to 12 years. There was no significant (p>0.01) difference between anthropometric indicators measured in November 1999 and November 2015 among Ellisras children with the same chronological age (5-12 years**).** Anthropometric indicators and BP of Ellisras rural children aged 5 to 12 years measured in November 1999 were analysed in the current study**.**

Table 1: Descriptive statistics for measurements carried out in November 1999 (n=1961) and November 2015 (n = 80) amongst Ellisras rural children aged 5 to 12 years.

	Nov 2015 Boys (n = 40) M (sd)	Nov 1999 Boys (n=1029) M (sd)	P- value	Nov 2015 Girls (n = 40) M (sd)	Nov 1999 Girls (n = 932) M (sd)	P-value
Height (cm)	136.1 (11.9)	132.8 (10.9)	0.057	131.9 (15.2)	133.3 (10.9)	0.435
SH	67.3 (4.7)	68.7 (4.8)	0.082	67.3 (6.8)	67.0 (4.8)	0.033
Weight (kg)	27.0 (7.7)	25.6 (5.2)	0.104	26.2 (9.5)	26.0 (6.0)	0.866
NC (cm)	25.3 (1.8)	25.6 (1.8)	0.272	24.8 (2.1)	25.1 (1.6)	0.349
MUAC (cm)	16.9 (1.9)	16.6 (1.5)	0.223	17.6 (3.4)	16.9 (1.8)	0.020

P<0.01: Significant; SH: Sitting height; NC: Neck circumference; MUAC: Mid upper arm circumference; n: sample size

4.1.1. DESCRIPTIVE STATISTICS OF MALNUTRITION AMONGST ELLISRAS RURAL CHILDREN

Table 2 showed descriptive statistics for weight, height, NC, MUAC, BMI and BP by gender and age group for Ellisras rural children aged 5 to 12 years. Boys (25.6 to 26.2 cm) showed a significantly (P< 0.05) higher mean NC than girls (25.0 to 25.8 cm) from age 9 to 11 years, while girls (17.9 cm) exhibited a significantly higher mean MUAC than boys (17.4 cm) at age 11 years. Boys and girls did not show any significant differences with their mean BP throughout the age range. Our current results agree with the study of Ferretti et al. (2015) which reported that NC was significantly high in boys than girls at the average age of 14.39 (girls) and 14.42 (boys) years from rural setting in Brazil. However, Ma et al. (2015) degrees that China MUAC was significantly high in girls than boys at the average of 9.4 (boys) and 9.5 (girls). This is due to the fact that at puberty adipocyte increases greatly in both girls and boys, but girls adipocyte increase far exceeding than boys (Malina et al., 2004).

Table 3 showed descriptive statistics for component of heights (height, SH, SHH and BP by gender and age group for Ellisras rural children aged 5 to 12 years. At age 12 years, girls mean height (145.6 cm) and SH (74.1 cm) were significantly ($P< 0.05$) higher than boys mean height (142.6 cm) and SH (72.8 cm). Boys and girls did not show any significant differences with their mean SH/H throughout the age range. Dangour et al. (2002) reported similar results on height and SH as being high amongst England girls than boys at age 12 years. This could be due to the fast growth rate of girls than boys between 10 and 13 years of age as reported by Alan et al. (2000) during this period.

Table 2: Descriptive statistics of absolute body size and blood pressure of Ellisras children aged 5-12 years carried out in November 1999.

	Sample size		Height (cm)		Weight (Kg)		NC (cm)		MUAC (cm)		SBP (mmHg)		DBP (mmHg)		BMI (Kg.m^{-2})		PP (mmHg)	
Age (yrs)	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
			M (sd)	M (sd)	M (sd)	M (sd)	M (sd)	M (sd)	M (sd)	M (sd)	M (sd)	M (sd)	M (sd)	M (sd)	M (sd)	M (sd)	M (sd)	M (sd)
5	53	37	111.6 (6.1)	110.2 (6.7)	17.3 (2.1)	17.1 (3.0)	23.9 (1.4)	23.4 (1.5)	15.0 (0.8)	15.1 (1.2)	100.6 (11.7)	102.3 (13.3)	61.3 (8.3)	59.4 (9.5)	13.9 (0.9)	14.0 (1.4)	39.3 (9.8)	42.9 (10.6)
6	64	58	116.9 (5.1)	116.5 (5.8)	18.9 (2.2)	18.7 (2.7)	24.1 (1.2)	23.6 (1.3)	15.1 (1.0)	15.5 (1.2)	102.1 (13.8)	98.4 (13.8)	61.3 (10.9)	59.7 (9.2)	13.8 (0.9)	13.7 (1.1)	40.8 (11.0)	38.8 (10.9)
7	97	73	122.2 (5.6)	122.7 (6.4)	20.9 (2.8)	20.8 (3.0)	24.8 (1.3)	24.3 (1.4)	15.7 (1.1)	15.8 (1.1)	96.9 (12.2)	96.3 (12.8)	59.7 (9.3)	57.5 (8.4)	13.9 (1.1)	13.8 (1.1)	37.1 (11.5)	38.8 (14.1)
8	117	115	127.7 (6.5)	127.3 (5.3)	23.4 (3.2)	22.8 (3.0)	25.3 (3.0)	24.6 (1.2)	16.1 (1.1)	16.2 (1.2)	97.3 (10.2)	96.4 (10.0)	59.1 (9.1)	59 (9.7)	14.3 (1.2)	14 (1.1)	38.2 (9.9)	37.4 (10.3)
9	184	180	133.5 (6.2)	133.1 (5.3)	25.5 (3.3)	25.4 (4.1)	25.6* (1.3)	25* (1.5)	16.5 (1.2)	16.5 (1.4)	99.7 (10.7)	99 (11.3)	61.9 (9.9)	61 (9.8)	14.3 (1.1)	14.3 (2.0)	37.9 (9.9)	38.0 (10.3)
10	231	220	137.7 (6.1)	137.1 (6.1)	27.6 (3.7)	27.5 (4.5)	26* (1.4)	25.3* (1.3)	17 (1.4)	17.1 (1.6)	99.5 (9.7)	99.7 (10.2)	60.2 (9.4)	59.8 (9.2)	14.5 (1.2)	14.6 (1.6)	39.3 (10.4)	39.9 (10.8)
11	187	178	141 (7.1)	142.1 (6.6)	29.3* (4.6)	30.4* (5.1)	26.2* (1.5)	25.8* (1.4)	17.4* (1.6)	17.9* (1.8)	101.6 (10.8)	102 (11.9)	62 (9.2)	60.9 (9.3)	14.7 (1.4)	15 (1.9)	39.6 (9.4)	41.1 (11.3)
12	96	71	142.6* (6.2)	145.6* (7.6)	30* (4.6)	32.5* (5.7)	26.5 (1.5)	26.4 (1.5)	17.5 (1.5)	18.5 (1.9)	101.9 (9.6)	101.8 (10.4)	60.8 (8.1)	63.1 (8.4)	14.7* (1.4)	15.3* (1.9)	41.1 (10.4)	38.7 (9.11)

SBP= Systolic blood pressure; DBP= Diastolic blood pressure= BMI= Body mass index; *= P<0.05;M= Mean; sd= standard deviation; NC= Neck circumference; MUAC= Mid upper arm circumference; PP= Pulse pressure.

Table 4 showed the prevalence of malnutrition using BMI and hypertension amongst Ellisras rural children aged 5-12 years. Low prevalence of hypertension (0 to 4.7%), and overweight/obesity (0 to 2.7%) using BMI were found amongst Ellisras rural children aged 5-12 years. The prevalence of underweight ranged from 0.9 to 41.6% in the severe, moderate and mild group.

Table 3: Descriptive statistics of components of height of Ellisras children aged 5-12 years carried out in November 1999.

	Sample size		Height (cm)		SH (cm)		SH/H (%)		LL (cm)	
Age (yrs)	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
			M (sd)	M (sd)	M (sd)	M (sd)	M (sd)	M (sd)	M (sd)	M (sd)
5	53	37	111.6 (6.1)	110.2 (6.7)	60.0 (2.7)	59.8 (3.6)	53.8 (1.8)	54.2 (1.4)	56.1 (3.9)	56.0 (4.8)
6	64	58	116.9 (5.1)	116.5 (5.8)	67.7 (3.2)	62.1 (2.0)	53.7 (2.1)	53.3 (1.2)	60.2 (4.2)	60.4 (3.8)
7	97	73	122.2 (5.6)	122.7 (6.4)	64.4 (2.7)	64.5 (2.9)	52.8 (1.3)	52.6 (1.8)	63.5 (3.7)	64.6 (4.5)
8	117	115	127.7 (6.5)	127.3 (5.3)	66.6 (3.4)	66.6 (2.6)	52.2 (1.5)	52.3 (1.1)	66.5 (7.0)	67.1 (3.6)
9	184	180	133.5 (6.2)	133.1 (5.3)	68.9 (3.2)	68.8 (2.7)	51.6 (1.1)	51.7 (1.3)	70.8 (4.1)	70.9 (3.8)
10	231	220	137.7 (6.1)	137.1 (6.1)	70.6 (3.1)	70.7 (3.2)	51.3 (1.4)	51.6 (1.6)	73.3 (4.2)	73.7 (3.8)
11	187	178	141.0 (7.1)	142.1 (6.6)	72.0 (3.5)	72.4 (3.2)	51.1 (1.5)	51.0 (1.5)	75.3* (4.7)	76.8* (4.2)
12	96	71	142.6* (6.2)	145.6* (7.6)	72.8* (3.3)	74.1* (3.8)	51.1 (1.2)	50.9 (1.3)	76.4* (4.1)	78.8* (4.8)

*= P <0.05; M= mean; sd= standard deviation; SH =Sitting height; SH/H= SH to height ratio; LL= Leg length.

Table 4: The prevalence of malnutrition using BMI and hypertension amongst Ellisras rural children aged 5-12 years carried out in November 1999.

	Sample size		High SBP		High DBP		Hypertension		Body mass index							
									Severe		Moderate		Mild		Overweight/Obese	
Age (yrs)	Boys	Girls	Boys %(n)	Girls %(n)	Boys %(n)	Girl %(n)	Boys %(n)	Girls %(n)	Boys %(n)	Girls %(n)	Boys %(n)	Girls %(n)	Boys %(n)	Girls %(n)	Boys %(n)	Girls %(n)
5	53	37	1.3	18.9	-	5.4	-	5.4	7.5	10.8	22.6	13.5	35.8	32.4	-	2.7
			(6)	(7)	-	(2)	-	(2)	(40)	(4)	(12)	(5)	(19)	(12)	-	(1)
6	64	58	14.1	17.2	9.4	1.7	4.7	-	9.4	8.6	17.2	13.8	34.4	34.5	-	-
			(9)	(10)	(6)	(1)	(3)	-	(6)	(5)	(11)	(8)	(22)	(20)	-	-
7	97	73	4.1	8.2	1.0	2.7	-	-	6.2	5.5	15.5	13.7	36.1	38.4	-	1.4
			(4)	(6)	(1)	(2)	-	-	(6)	(4)	(15)	(10)	(35)	(28)	-	(1)
8	117	115	0.9	1.7	0.9	3.5	-	-	0.9	4.3	11.1	12.2	40.2	33.9	0.9	-
			(1)	(2)	(1)	(4)	-	-	(1)	(5)	(13)	(14)	(47)	(39)	(1)	-
9	184	180	2.7	3.3	2.2	3.3	1.1	1.1	6	3.9	13.6	21.1	38.0	32.2	-	0.6
			(5)	(6)	(4)	(6)	(2)	(2)	(11)	(7)	(25)	(38)	(70)	(58)	-	(1)
10	231	220	0.4	2.3	-	2.7	-	1.4	4.8	7.3	14.7	13.6	41.6	40	-	2.3
			(1)	(5)	-	(6)	-	3	(11)	(16)	(34)	(30)	(96)	(88)	-	(5)
11	187	178	1.1	2.2	0.5	1.7	0.5	0.6	5.9	9.6	19.8	14.6	41.2	41.0	-	1.7
			(2)	(4)	(1)	(3)	(1)	(1)	(11)	(17)	(37)	(26)	(77)	(73)	-	(3)
12	96	71	1.0	-	-	-	-	-	13.5	15.5	18.8	15.5	38.5	32.4	-	1.4
			(1)	-	1	-	-	-	(13)	(11)	(18)	(11)	(37	(23)	-	(1)

SBP: Systolic blood pressure; DBP: Diastolic blood pressure; n: sample size.

Figure 3 and 4 showed the comparison of mean SH and SH/H between Ellisras children and NHANES children aged 5-12 years. There was an increase in mean SH with age, where Ellisras rural children had low mean SH than NHANES children for both gender, except on age 5 years which showed a contradiction in boys (figure 3). Figure 4 exhibit the decrease in SH/H inversely with age. Mean SH/H amongst Ellisras children were low compared with the NHANES children for both genders.

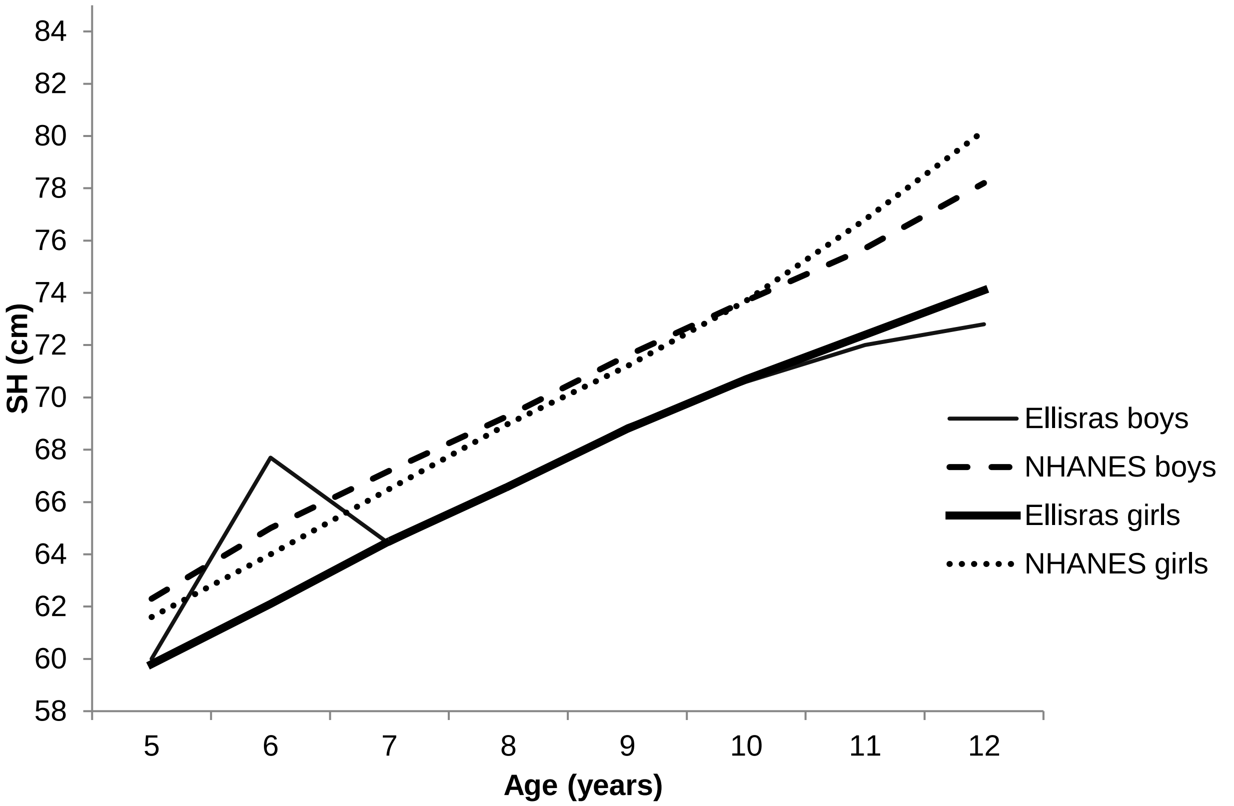

Figure 4: The comparison of SH in Elliras and NHANES children aged 5-12 years.

The prevalence of overweight, obesity and high BP of the cited studies (Hedley et al., 2004; Sorof et al., 2004) were high compared to the current study. This could be as a results of the high prevalence of underweight in the current study (Table 4). These differences may be due to the fact that those studies were carried out in developed countries in contrast to our study which is exclusively based on under-resourced rural settings. According to WHO (2011) the prevalence of overweight or obesity increases as the country develops.

The comparison of NHANES children with Ellisras rural children (Figures 2 and 3) supports the previous study of Monyeki et al. (2000) which stated that Ellisras rural children were underweight. Feber et al. (2015) reported underweight in four different areas (two from rural and two from urban areas) in South Africa. However, it is possible that nowadays the aforementioned changes and developments such as high socio economic status and life style changes in South Africa have resulted in increased body stature for children (Van Den Ende et al., 2014).

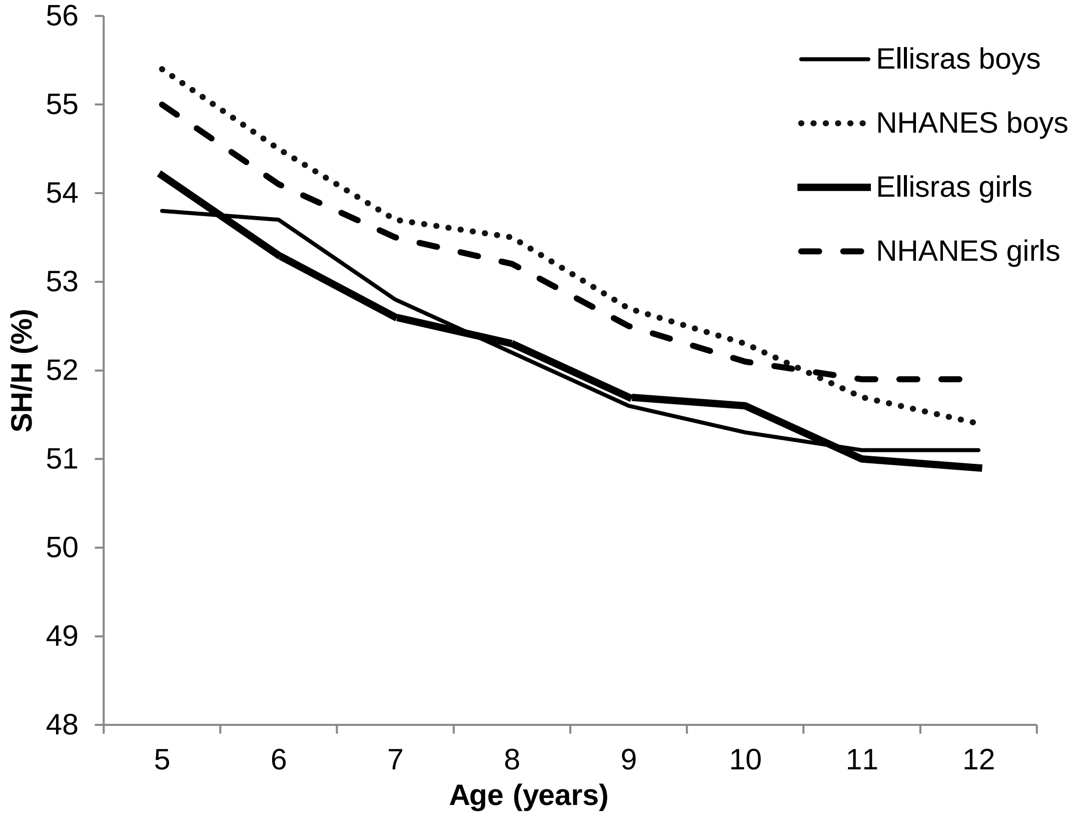

Figure 5: The comparison of SH/H in Ellisras and NHANES children aged 5-12 years.

4.1.2. THE RELATIONSHIP BETWEEN BP AND ANTHROPOMETRIC INDICATORS IN CHILDREN

Table 5 showed linear regression co-efficients, P-value and 95% confidence intervals for the association between neck circumferences (NC), mid upper arm circumference (MUAC) with blood pressures in Ellisras children aged 5-12 years. The regression analysis showed a positive significant ($P<0.05$) association for SBP with NC (β=0.764, 95%CI 0.475 to 1.052) and MUAC (β=1.286, 95% CI 0.990 to 1.581) for unadjusted and adjusted for age and gender. NC (β=0.628 95% CI 0.303 to 0.953) and MUAC (β=1.351 95% CI 1.004 to 1.697) showed a significant association with SBP. However, MUAC had a significant association with DBP for both unadjusted and adjusted for age and gender.

Table 5: Linear regression coefficients, P-value and 95% confidence intervals for the association between Neck circumference (NC), mid upper arm circumference (MUAC) and blood pressures in Ellisras children age 5-12 years.

	Unadjusted				Adjusted for age and gender			
	β	P-value	95% CI		β	P-value	95% CI	
SBP								
NC	0.764	0.000	0.475	1.052	0.628	0.000	0.303	0.953
MUAC	1.286	0.000	0.990	1.581	1.351	0.000	1.004	1.697
DBP								
NC	0.325	0.009	0.082	0.568	0.186	0.182	-0.087	0.460
MUAC	0.578	0.000	0.327	0.829	0.563	0.000	0.269	0.857

β: Beta, CI: Confidence Interval, SBP: Systolic Blood Pressure; DBP: Diastolic Blood Pressure.

For the association of anthropometrics and BP, Nafiu et al. (2014) found a positive association between BP and NC in American children aged 6-18 years. NC showed an independent association with various cardiometabolic risk markers including BP and had strong correlation with BMI (Kurtoglu et al., 2012; Nafiu et al., 2010). Mazıcıoğlu et al. (2010) reported that in Turkey MUAC is strongly associated with both SBP and DBP in adolescents aged 11-17 years. Bassareo et al. (2013) also reported that MUAC had a significant relationship with SBP but not DBP in Sardinian children aged 11-14 years. Therefore the present study concurs with the previous studies on the association of NC and MUAC with BP.

In our study, we did not consider the socio-economic status of families of the participants in the analysis. Furthermore, even though the data of the study was collected in the year 1999, it is possible that the prevalence of overweight and obesity has increased, at the present time, due to developments and changes such as high socio economic status and life style changes in South Africa (Van Den Ende et al., 2014).

The anthropometric and BP measurements were taken directly, and hence recall or estimation bias will not prevail in our study. In addition, we measured BP during early childhood, demonstrating that proper monitoring should be started from child's early days from a viewpoint of screening for vulnerable individuals (Ciccone et al., 2013).

4.1.3. THE RELATIONSHIP BETWEEN COMPONENT OF HEIGHTS AND BP IN CHILDREN

Table 6 showed linear regression coefficients, P-value and 95% confidence intervals for the association between sitting height (SH), SH to height ratio (SH/H) and blood pressures (BP) in Ellisras children aged 5-12 years. The regression analysis showed a positive significant ($P < 0.001$ and 0.05) association between SBP with height and SH (β ranged from 0.127 to 0.134 and 95% CI ranged from 0.082 0.172 to 0.210 0.415). DBP also showed a positive significant ($P < 0.001$ and 0.05) association with Height and SH (β ranged from 0.080 to 0.088 and 95% CI 0.042 0.118 to 0.086 0.259). After adjusted for age and gender, both SBP and DBP showed a positive significant ($P < 0.001$ and 0.05) association with height and SH.

Our findings, showed that height and SH of these children were significantly ($P<0.05$) associated with SBP and DBP for both unadjusted and adjusted for age and gender. Furthermore, height, SH and SH/H discriminated children with elevated BP amongst Ellisras children aged 5-12 years. Thus, agrees with Marcato et al. (2014) who reported that SH was significantly associated with both SBP and DBP, while SH/H did not show any significant association with SBP and DBP in Brazilian children aged 6 to 13 years. Zhang et al. (2015) also showed that both SBP and DBP had a stronger association with SH in Chinese children aged 7 to 18 years.

Table 6: Linear regression coefficients, P-value and 95% confidence intervals for the association between sitting height (SH), SH to height ratio (SH/H), Leg length (LL) blood pressures (BP) in Ellisras children age 5-12 years.

	Unadjusted				Adjusted for age and gender, BMI and WC			
	β	P-value	95% CI		β	P-value	95% CI	
SBP								
Height	0.127	0.000	0.082	0.172	0.166	0.000	0.085	0.246
SH	0.134	0.000	0.210	0.415	0.161	0.000	0.220	0.532
LL	0.187	0.000	0.119	0.255	0.037	0.606	-0.102	0.176
SHH	-0.023	0.316	-45.141	14.575	0.025	0.333	-17.228	50.869
DBP								
Height	0.080	0.000	0.042	0.118	0.115	0.001	0.047	0.182
SH	0.088	0.000	0.086	0.259	0.101	0.003	0.066	0.329
LL	0.121	0.000	0.064	0.179	0.123	0.041	0.005	0.241
SHH	-0.044	0.054	-49.629	0.407	-0.018	0.480	-38.884	18.300
PP								
Height	0.047	0.033	0.004	0.090	-0.029	0.530	-0.120	0.062
SH	0.140	0.050	0.041	0.238	0.040	0.650	-0.135	0.213
LL	0.065	0.048	0.001	0.130	-0.086	0.205	-0.220	0.047
SH/H	9.328	0.518	-18.993	37.649	29.449	0.049	-4.441	63.338

β = beta; CI= confidence interval; SBP= Systolic blood pressure; DBP= diastolic blood pressure; PP= Pulse pressure; BMI= Body mass index; WC= waist circumference.

The possible explanation for the current results could be linked to the 'hydrostatic column of blood hypotheses formulated by Kahn et al. (1986). Briefly, hydrostatic pressure at a given point increases in proportion to the height of a liquid column because of the increasing weight of fluid exerting downward force from above. As a consequence, to ensure adequate perfusion of a child's brain, BP at heart level must exceed the hydrostatic pressure induced by the vertical distance between the heart and the head of which the components of height may best predict BP at heart level (Regnault et al., 2014). The giraffe provides a classic example. Giraffe's arterial pressure is a consequence of a baroreceptor-regulated mechanism that results in the generation of sufficient hydrostatic pressure to overcome gravitational effects, and to supply the head with blood at a pressure of about 100 mmHg (Mitchell et al., 2006). To generate this pressure, a giraffe's mean arterial BP is approximately 200mmHg (Brøndum et al., 2009).

Reduced fetal and infant growth which could be related to adult height increases the risk of cardiovascular diseases in adulthood (Barker et al., 1989). The recognition of significant association between components of height and BP in rural South African children in the present study could help target prevention towards high-risk of CVD in this age group as evident in other studies (Khan et al., 2008; Monyeki et al., 2008).

4.1.4. ABILITY OF ANTHROPOMETRIC INDICATORS TO CORRECTLY DISCRIMINATE CHILDREN WITH HIGH BP

Table 7 Gender-specific areas under the receiver operating characteristic (ROC) curves showing the ability of anthropometric measures identify children with high BP. Areas under curve (AUC) for NC (0.698), MUAC (0.677) and BMI (0.636) for boys were statistically significant (P<0.05) for high SBP, while in girls AUC of BMI was not significant (P>0.05) for high DBP. Table 8 Areas under the ROC showed the ability of SH and SH/H to identify Ellisras children with high BP. Height (AUC = 0.700, 95%CI 0.581 to 0.818), SH (AUC= 0.690, 95%CI 0.573 to 0.786) and SH/H (AUC=0.670, 95% 0.533 to 0.807) significantly (P<0.05) can identify Ellisras children with hypertension.

.

Table 7: Gender-specific areas under the receiver operating characteristic (ROC) curves showing the ability of anthropometrics measures to identify children with high BP.

	High systolic blood pressure			High diastolic blood pressure			Hypertension		
ROC analysis	AUC	95%CI		AUC	95%CI		AUC	95%CI	
Boys									
NC	0.698*	0.596	0.800	0.729*	0.588	0.871	0.409	0.174	0.644
MUAC	0.677*	0.589	0.775	0.656*	0.513	0.798	0.449	0.247	0.651
BMI	0.636*	0.532	0.740	0.557	0.425	0.688	0.546	0.411	0.681
Girls									
NC	0.606*	0.516	0.696	0.442	0.332	0.552	0.410	0.247	0.574
MUAC	0.640*	0.551	0.729	0.450	0.324	0.576	0.363	0.168	0.559
BMI	0.550	0.461	0.638	0.430	0.297	0.563	0.398	0.184	0.612

*P<0.05; AUC: Area Under Curve; NC: Neck Circumference; MUAC: Mid Upper Arm Circumference; BMI: Body Mass Index.

Few studies have reported the association of high BP and several anthropometric indicators. However, it is still controversial whether absolute (general adiposity) or relative body fat (central adiposity) is a better predictor for hypertension (Spiegelman et al., 1992) or not.

Most studies are supporting central adiposity as the good predictor for high BP (Han et al., 1995; Hansen et al., 2007). NC and waist circumference (WC) as a marker of central adiposity appeared to have the accuracy of discriminating children with high BP in America (Nafiu et al., 2014; Watts et al., 2008). Moreover, compared with waist circumference, NC seems to be an ideal measure as it does not change during the day (Laakso et al., 2002). The present study agrees with the previous studies as NC discriminated children with high BP and also added that MUAC can also be used to identify children with high BP.

Table 8: Areas under the receiver operating characteristic (ROC) curves showing the ability of SH and SH/H to identify Ellisras children with high BP.

	High Systolic Blood pressure			High diastolic blood pressure			Hypertension		
ROC analysis	AUC	95% CI		AUC	95% CI		AUC	95%CI	
Height	0.746*	0.686	0.806	0.628*	0.551	0.704	0.700*	0.581	0.818
SH	0.736*	0.678	0.795	0.581	0.503	0.660	0.69*	0.573	0.786
SH/H	0.659*	0.592	0.726	0.618*	0.534	0.701	0.670*	0.533	0.807

*P<0.05; AUC: Area Under Curve; Cl: Confident intervals

4.1.5. NC AND MUAC CUT-OFF POINTS FOR UNDERWEIGHT

Table 9-10 showed age and gender optimal cut off points for NC and MUAC in Ellisras rural boys for underweight. The results showed that 12 year old girl with NC<26.2 cm and MUAC<18.6 cm is more likely to be underweight.

Table 9: Optimal cut-off points for NC and MUAC in Ellisras rural boys for underweight.

Age (years)	Variables	AUC-ROC (95% CI)	Cut-off value	Sensitivity	Specificity	PPV	NPV
5	NC	0.582 (0.414-0.750)	23.2	37.1	72.2	1.33	0.87
	MUAC	0.677 (0.516-0.839)	14.8	42.9	72.2	1.54	0.79
6	NC	0.850 (0.755-0.946)	24.1	66.7	84.0	4.17	0.40
	MUAC	0.874 (0.791-0.958)	15.5	76.9	80.0	3.85	0.29
7	NC	0.749 (0.652-0.847)	24.7	62.5	75.6	2.56	0.50
	MUAC	0.873(0.805-0.942)	15.8	78.6	85.4	5.38	0.25
8	NC	0.770 (0.685-0.856)	24.8	63.9	80.4	3.26	0.45
	MUAC	0.820 (0.746-0.893)	16.0	65.6	83.9	4.07	0.41
9	NC	0.767 (0.700-0.834)	25.5	60.4	78.2	2.77	0.51
	MUAC	0.854 (0.800-0.907)	16.4	69.8	80.8	3.64	0.37
10	NC	0.802 (0.742-0.861)	25.9	63.1	80.0	3.16	0.46
	MUAC	0.872 (0.825-0.920)	17.2	80.9	80.0	4.05	0.24
11	NC	0.732 (0.657-0.806)	26.1	62.4	75.8	2.58	0.50
	MUAC	0.866 (0.811-0.922)	17.5	73.6	83.9	4.57	0.31
12	NC	0.810 (0.657-0.806)	26.1	62.4	75.8	2.58	0.50
	MUAC	0.929 (0.882-0.977)	18.0	82.4	85.7	5.76	0.21

AUC: Area Under Curve; ROC: Receiver Operative Characteristics; NC: Neck Circumference; MUAC: Mid Upper Arm Circumference; PPV: Positive Predictive Value; NPV: Negative Predictive Value.

In this study, age and gender optimal NC and MUAC cut off points for underweight in children were established using BMI. However other studies established their cut off points for overweight or obesity in other countries like Turkey and Brazil (Mazıcıoğlu et al., 2010; Nafiu et al., 2010).Therefore, this was the first study to introduce the cut off points for underweight in children from South Africa by age and gender based on international BMI cut off points.

Table 10: ROC curve analysis of NC and MUAC in Ellisras rural girls for underweight.

Age (years)	Variables	AUC-ROC (95% CI)	Cut-off value	Sensitivity	Specificity	PPV	NPV
5	NC	0.789 (0.644-0.933)	23.3	57.1	81.2	1.06	0.23
	MUAC	0.878 (0.765-0.991)	15.4	85.7	81.2	4.50	0.18
6	NC	0.817 (0.704-0.930)	23.4	57.6	80.0	2.88	0.53
	MUAC	0.839 (0.740-0.939)	15.5	72.7	84.0	4.54	0.33
7	NC	0.766 (0.654-0.877)	23.9	52.4	83.9	3.25	0.57
	MUAC	0.835 (0.741-0.930)	15.8	71.4	80.6	3.68	0.35
8	NC	0.726 (0.634-0.819)	24.1	51.7	75.4	2.10	0.64
	MUAC	0.871 (0.806-0.936)	16.3	81.0	82.5	4.63	0.23
9	NC	0.713 (0.638-0.788)	24.6	59.2	79.2	2.85	0.52
	MUAC	0.871 (0.821-0.922)	16.5	75.7	83.1	4.48	0.29
10	NC	0.681 (0.611-0.751)	25.0	50.0	80.2	2.53	0.62
	MUAC	0.868 (0.821-0.914)	17.1	74.6	80.2	3.77	0.32
11	NC	0.758 (0.682-0.833)	25.6	58.6	75.8	2.42	0.55
	MUAC	0.864 (0.805-0.925)	18.0	80.2	79.0	3.82	0.25
12	NC	0.779 (0.669-0.890)	26.2	62.2	80.8	3.24	0.47
	MUAC	0.910 (0.842-0.978)	18.6	84.4	80.8	4.40	0.19

AUC: Area Under Curve, ROC: Receiver Operative Characteristics, NC: Neck circumference, MUAC: Mid Upper Arm circumference, PPV: Positive Predictive Value; NPV: Negative Predictive Value.

4.1. REFERENCES

Alan DR, Pamela AC, James NR. (2000). Growth and pubertal development in children and adolescents: effects of diet and physical activity. *Am J Clin Nutr*, 72: 521S–528S.

Barker DJP, Winter PD, Osmond C, Margetts B, Simmonds SJ. (1989). Weights in infancy and death from ischaemic heart disease. *Lancet,* 2:577-580.

Bassareo PP, Marras AR, Barbanti C, Mercuro G. (2013). Comparison between waist and mid-upper arm circumferences in influencing systolic blood pressure in adolescence: the SHARP (Sardinian Hypertensive Adolescent Research Programme) study. *JPNIM*, 2:e020207.

Brøndum E, Hasenkam JM, Secher NH. (2009).Jugular venous pooling during lowering of the head affects blood pressure of the anesthetized giraffe. *Am J Physiol Regul Integr Comp Physiol*, 297:1058–1065.

Ciccone MM, Scicchitano P, Salerno C, Gesualdo M, Fornarelli F. (2013). Aorta structural alterations in term neonates: the role of birth and maternal characteristics. *Biomed Res Int*, 2013: 459168.

Dangour AD, Schilg S, Hulse JA, Cole TJ. (2002). Sitting height and subischial leg length centile curves for boys and girls from Southeast England. *Ann Hum Biol*, 29: 290-305.

Feber M, van Jaarveld PJ, Kunneke E, Kruger HS, Schoeman SE, van Stuijvenberg ME. (2015). Vitamin A and anthropometric status of South African preschool children from four areas with known distinct eating patterns**.** *Nutrition*, 31:64-71.

Ferretti Rde L, Cintra Ide P, Passos MA, de Moraes Ferrari GL, Fisberg M. (2015). Elevated neck circumference and associated factors in adolescents. *BMC Public Health*, 15:208.

Han TS, van Leer EM, Seidell JC, Lean ME. (1995). Waist circumference action levels in the identification of cardiovascular risk factors: prevalence study in a random sample. *BMJ*, 311: 1401-1405.

Hansen ML, Gunn PW, Kaelber DC. (2007). Underdiagnosis of hypertension in children and adolescents. *JAMA,* 298: 874-879.

Hedley AA, Ogden CL, Johnson CL, Carroll MD, Curtin LR, Flegal KM. (2004). Prevalence of overweight and obesity among US children, adolescents, and adults, 1999-2002. *JAMA*, 291:2847-50.

Kahn HS, Bain RP, Pullen-Smith B. (1986). Interpretation of children's blood pressure using a physiologic height correction. *J Chronic Dis*, 39:521–531.

Khan A, Haq FU, Pervez MB, Saleheen D, Frossard PM, Ishaq M. (2008). Anthropometric correlates of blood pressure in normotensive Pakistani subjects. *Int J Cardiol*, 124:259-262.

Kurtoglu S, Hatipoglu N, Mazicioglu MM, Kondolot M. (2012). Neck circumference as a novel parameter to determine metabolic risk factors in obese children. *Eur J Clin Invest*, 42: 623-630.

Laakso M, Matilainen V, Keinänen-Kiukaanniemi S. (2002). Association of neck circumference with insulin resistance-related factors. *Int J Obes Relat Metab Disord*, 26: 873-875.

Ma CM, Li Y, Gao GQ, Yin FZ, Wang R, Liu XL, Lu Q. (2015). Mid-upper arm circumference as a screening measure for identifying children with hypertension. *Blood Press Monit,* 20:189-193.

Malina RM, Bouchard C, Bar-Or O. (2004). *Growth,Maturation and physical activity*. Human genetics: Champaign, IL.

Marcato DG, Sampaio JD, Alves ERB, de Jesus JSA, Fuly JTB, Giovaninni NPB. (2014). Sitting-height measure are related to body mass index and blood pressure in children. *Arq Bras Endocrinol Metab*, 58:802-806.

Mazıcıoğlu MM, Hatipoğlu N, Oztürk A, Ciçek B, Ustünbaş HB. (2010). Waist circumference and mid-upper arm circumference in evaluation of obesity in children aged between 6 and 17 years. *J Clin Res Pediatr Endocrinol*, 2: 144-150.

Mitchell G, Maloney SK, Mitchell D, Keegan DJ. (2006). The origin of mean arterial and jugular venous blood pressures in giraffes. *J Exp Biol,* 209:2515–2524.

Monyeki KD, Cameron N, Getz B. (2000).Growth and nutritional status of rural South African children 3-10 years old: The Ellisras growth study. *Am J Hum Biol*, 12:42-49.

Monyeki KD, Kemper HCG. (2008). The risk factors for elevated blood pressure and how to address cardiovascular risk factors: a review in pediatric populations. *J Hum Hypertens*, 22:450-459.

Nafiu OO, Burke C, Lee J, Voepel-Lewis T, Malviya S. (2010). Neck circumference as a screening measure for identifying children with high body mass index. *Pediatrics*, 126: 306-310.

Nafiu OO, Zepeda A, Curcio C, Prasad Y. (2014). Association of neck circumference and obesity status with elevated blood pressure in children. *J Hum Hypertens*, 28: 263-268.

Regnault N, Kleinman KP, Rifas-Shiman SL, Lengenberg C, Lipshultz SE, Gillman MW. (2014). Componets of height and blood pressure in childhood. *Int J Epidemol*, 43: 149-159.

Sorof JM, Lai D, Turner J, Poffenbarger T, Portman RJ. (2004). Overweight, ethnicity, and the prevalence of hypertension in school-aged children. *Pediatrics*, 113:475-482.

Spiegelman D, Israel RG, Bouchard C, Willett WC. (1992). Absolute fat mass, percent body fat, and body-fat distribution: which is the real determinant of blood pressure and serum glucose. *Am J Clin Nutr*, 55:1033-1044.

Van Den Ende C, Twisk JW, Monyeki KD. (2014). The relationship between body mass index and dietary intake of primary school children from rural area of South Africa: The Ellisras longitudinal study. *Am J Hum Biol*, 26:701-706.

Watts K, Bell LM, Byrne SM, Jones TW, Davis EA. (2008). Waist circumference predicts cardiovascular risk in young Australian children. *J Paediatr Child Health*, 44: 709-715.

World Health Organization. (2011). *Global strategy on diet, physical activity and health.* What is overweight and obesity. Geneva: World Health Organization.

Zhang Y, Zhao J, Chu Z, Wang L. (2015).The association between components of height and blood pressure among children and adolescents in Shandong, China. *Int J Cardiol*, 182:18-19.

CHAPTER 5

INTRODUCTION, SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1. INTRODUCTION

Cardiovascular diseases (CVDs) are some of the non-communicable diseases that increase every year and are associated with morbidity and mortality (Sliwa et al., 2008).The risk factors of CVDs are mostly malnutrition and hypertension. Furthermore, these risk factors start at early age and increase till adulthood (Twagirumukiza et al., 2011). The prevalence of malnutrition and hypertension in children is increasing even in the developing country (Puoane et al., 2002; Monyeki et al., 2008). However, little is known about the relationship between anthropometric indicators and blood pressure in children from the developed countries. Nafiu et al. (2014) and Kemper (2004) reported significantly associated anthropometric indicators with BP in children of the developed countries.

5.2. SUMMARY

Chapter 1 addressed the need for studying the relationship between anthropometrics indicators and BP among rural children in Ellisras area in Limpopo province, South Africa. The need for establishing the cut off points for malnutrition in Ellisras rural children was indicated. In order to answer the above-mentioned statements successfully, the following objectives of the study were outlined in the first chapter:

i. To test for period of measurements effect of all the anthropometric indicators (NC, MUAC, Height, Weight, SH and SH/H) to be used in the study.

ii. To investigate the prevalence of malnutrition using international BMI cut-off points.

iii. To compare the SH and SH/H of Ellisras children with reference data (National Health and Nutrition Examination Survey III)

iv. To determine the association between BP and anthropometrics indicators (NC, MUAC, SH and SH/H) among Ellisras rural children aged 5 -12 years.

v. To determine the sensitivity and specificity of NC and MUAC based on BMI international cut off points among Ellisras rural children.

In Chapter 2, literature on the topic was reviewed. We reviewed the literature of some important international researchers who argued that anthropometric indicators are associated with BP in children and adolescents (Bassaroe et al., 2013; Marcato et al., 2014; Nafiu et al., 2014; Kuciene et al., 2015; Dong et al., 2016)

Chapter 3- Indicated the methodology and the statistical analysis of the data collected. Linear regression was used to determine the association between anthropometric indicators and BP among Ellisras rural children.

Chapter 4, described the results and discussion of the study. There was significant ($P<0.05$) association between anthropometrics indicators with BP among Ellisars rural children aged 5-12 years. Therefore, the present study concurs with the previous studies on the association of anthropometric indicators with BP in children and adolescents (Nafiu et al., 2014; Kuciene et al., 2015; Dong et al., 2016).

In chapter 5, a summary overview of the dissertation was presented together with recommendations of the study which will help to uproot the dynamics of CVD among a paediatric population in rural South Africa.

5.3. CONCLUSIONS

The conclusions of the study are provided in relation to the objectives and hypothesis set out in Chapter 1.

Objective 1: To test for period of measurements effect of all the anthropometric indicators (NC, MUAC, Height, Weight, SH and SH/H).

Hypothesis 1: The anthropometrics indicators for Ellisras rural children of the same chronological age measured in November 1999 and November 2015 will be similar.

Anthropometric indicators measured in November 1999 and November 2015 on the same chronological age of Ellisras rural children were tested (p<0.01) using student t-test. There was no significant difference between measurements taken in November 1999 and November 2015. It is worth mentioning that the same measurements were taken under the same season (November) in the Ellisras rural area which is characterised by the onset of the rainy season. Furthermore, the slow socio-economic development of Ellisras rural area as reported by Monyeki et al. (2010) and

Statistics South Africa (2002) could add to the environmental circumstances thatthe Ellisras rural community reside under. Consequently, similar results of period of measurement effects were reported by Van Lenthe et al. (1996) between Amsterdam Longitudinal Growth and Health Study children living in the same environment and season in the Netherlands.

Anthropometric indicators measured in November 1999 were analysed in the current study.

In the light of the above findings, hypothesis 1 was therefore partially accepted.

Objective 2: To investigate the prevalence of malnutrition based on international BMI cut-off points.

Hypothesis 2: The prevalence of underweight will be high compared to overweight amongst Ellisras rural children.

Overall high prevalence of underweight (severe, moderate and mild) (ranged 0.9 to 41.6%) was observed compared to overweight (ranged 0 to 2, 7%) among Ellisras children aged 5-12 years. Similar prevalence of underweight in children from Limpopo province (urban and rural) were reported to be 12.1% in a national study by Reddy et al. 2003. This could be due to low energy intake experienced by most Limpopo rural area children and the poor dwelling conditions these children live under as reported by Steyn et al. (1992) and Labadarios et al. (2000).

In the light of the findings above, hypothesis 2 was therefore partially accepted.

Objective 3: To Compare the SH and SH/H of Ellisras children with reference population (National Health and Nutrition Examination Survey III).

Hypothesis 3: SH and SH/ H of Elliras children will be low compared to the reference population

The results of the current study showed that SH and SH/H of Ellisras children were low compared to high SH and SH/H of reference population. The net results of poor nutrition environment in which the Ellisras rural children live were, an increasing prevalence of heights, weight and BMI less than the reference stands by 10 years of age (Monyeki et al., 2000; Feber et al., 2015). However, nowadays the migration of South African population to urban areas and the steady developments of rural areas coupled with the consumption of fast fatty food had resulted in better nutritional status in children compared to the past decade (Puoane et al.2006; Malhotra et al., 2008; Van Den Ende et al., 2014).

In the light of the findings above, hypothesis 3 was therefore partially accepted.

Objective 4: To determine the association between BP and anthropometrics indicators (NC, MUAC, SH and SH/H) among Ellisras rural children aged 5 -12 years.

Hypothesis 4: There will be a significant association between anthropometrics and BP among Ellisras rural children.

There was a positive significant association between BP and anthropometric indicators in this study population, though the association of DBP and NC disappeared after adjustments for age and gender. Furthermore, there is a positive significant association between DBP and SBP with the components of height amongst Ellisras rural children. NC and MUAC can predict both high SBP and DBP in boys while in girls NC and MUAC can only predict high SBP. However, BMI can predict high SBP for boys only. Nafiu et al. (2014) found a positive association between BP and NC in

American children aged 6-18 years. Furthermore, Marcato et al. (2014) reported that SH was significantly associated with both SBP and DBP, while SH/H did not show any significant association with SBP and DBP in Brazilian children aged 6 to 13 years

In the light of the findings above, hypothesis 4 was therefore partially accepted.

Objective 5: To determine the sensitivity and specificity of NC and MUAC based on BMI international cut off points among Ellisras rural children.

Hypothesis 5: The sensitivity and specificity cut off points for NC and MUAC will be established amongst Elliras rural children aged 5-12 years.

The AUC, cut-off value, sensitivity and specificity for underweight of each age and gender were established. The cut off values for underweight in Ellisras children increases with age. However, similar results were reported for overweight and obese children by Mazıcıoğlu et al. (2010) and Nafiu et al. (2010). Therefore this current study was the first to establish NC and MUAC cut off points for underweight in children from South Africa. Moreover, NC and MUAC are the simple techniques with good interrater reliability and could be used to screen underweight in children

In the light of the findings above, hypothesis 5 was therefore partially accepted.

5.4. RECOMMENDATIONS

We recommend that:

i. NC and MUAC cut off points be established in other African countries in the continent. According to Kurtoglu et al. (2012) and Lu et al. (2014), NC and MUC are increasingly recognized as a useful indexes reflective of both fat distribution and risk of metabolic syndrome. While the use of BMI as a surrogate for fat distribution among children raises debates. The primary contribution of this present study was that both NC and MUAC can be substituted for one another as an additional evaluation tool next to BMI in detecting underweight in the Ellisras rural children.

ii. Additionally, these two indices may also be used in epidemiologic studies to assess cardiovascular and metabolic rates in rural South African children.

iii. Anthropometric indicators are popular, cheap and non-invasive methods. Especially in epidemiologic studies, NC and MUAC are practical tools and can be easily measured in almost any situation.

iv. Further studies are needed on the relationship between components of height, anthropometric indicators and CVDs risk factors overtime in rural South African children.

v. Early intervention and management of under nutrition in Ellisras rural children could benefit the growing rural South African population as CVDs risk factors associated with under nutrition will be combated at an early age.

vi. Blood samples should be included in the ELS.

- To investigate the development of biological and behavioural risk factors for CVDs and/or diabetes in rural South African population over time.

- To investigate the changes that occur in serum levels of a variety of biochemical parameters related to CVDs, under nutrition, obesity and diabetes in this rural South African population over time.

5.5. REFERERENCES

Bassareo PP, Marras AR, Barbanti C, Mercuro G. (2013) Comparison between waist and mid-upper arm circumferences in influencing systolic blood pressure in adolescence: the SHARP (Sardinian Hypertensive Adolescent Research Programme) study. *JPNIM*, 2:e020207.

Dong B, Wan Z, Ma J. (2016). Leg to trunk ratio and the risk of hypertension in children and adolescents: a population-based study. *J Public Health*, 203: doi: 10.1093.

Feber M, van Jaarveld PJ, Kunneke E, Kruger HS, Schoeman SE, van Stuijvenberg ME. (2015). Vitamin A and anthropometric status of South African preschool children from four areas with known distinct eating patterns. *Nutrition*, 31:64-71.

Kemper HCG. (2004). *Amsterdam growth and health longitudinal study: A 23 year follow up from teenager to adult about lifestyle and health.* New York: Karger press, pp 1-20.

Kurtoglu S, Hatipoglu N, Mazicioglu MM, Kondolot M. (2012). Neck circumference as a novel parameter to determine metabolic risk factors in obese children. Eur J Clin Invest, 42:623-630.

Kuciene R, Dulskiene V, Medzioniene J. (2015). Association of neck circumference and high blood pressure in children and adolescents: a case-control study. *BMC Pediatr*, 15:127. doi: 10.1186/s12887-015-0444-2.

Labadarios D, Steyn NP, Maunder E. (2000). *The National Food Consumption survey: Children aged 1 -9 years, South Africa, 1999*. Pretoria: Department of Health.

Lu Q, Wang R, Lou DH, Ma CM, Liu XL, Yin FZ. (2014). Mid-upper-arm circumference and arm-to-height ratio in evaluation of overweight and obesity in Han children. Pediatr Neonatol, 55:14-19.

Malhotra R, Hoyo C, Ostbye T, Hughes G, Schwartz D, Tsolekile L , Tuoane T (2008). Determinants of obesity in an urban townshop of South Africa. *SA J Clin Nutr* 21: 315-320

Marcato DG, Sampaio JD, Alves ERB, de Jesus JSA, Fuly JTB, Giovaninni NPB. (2014). Sitting-height measure are related to body mass index and blood pressure in children. *Arq Bras Endocrinol Metab*, 58:802-806.

Mazıcıoğlu MM, Hatipoğlu N, Oztürk A, Ciçek B, Ustünbaş HB. (2010). Waist circumference and mid-upper arm circumference in evaluation of obesity in children aged between 6 and 17 years. *J Clin Res Pediatr Endocrinol*, 2: 144-150.

Monyeki KD, Kemper HCG, Twisk JWR. (2010). *Trends in obesity and hypertension in South African youth. In O` Dea JA and Eriksen M. (Eds) Childhood prevention-International Research, controversies and intervention*. Sydney: Oxford University Press.

Monyeki KD, Cameron N, Getz B. (2000).Growth and nutritional status of rural South African children 3-10 years old: The Ellisras growth study. *Am J Hum Biol*, 12:42-49.

Monyeki KD, Kemper HCG, Makgae PJ. (2008). Relationship between fat patterns, physical fitness and blood pressure of rural South African children: Ellisras Longitudinal Growth and Health Study*. J Hum Hypertens*, 22: 311–319.

Nafiu OO, Burke C, Lee J, Voepel-Lewis T, Malviya S. (2010). Neck circumference as a screening measure for identifying children with high body mass index. *Pediatrics,* 126: 306-310.

Nafiu OO, Zepeda A, Curcio C, Prasad Y. (2014). Association of neck circumference and obesity status with elevated blood pressure in children. *J Hum Hypertens*, 28: 263-268.

Puoane T, Matwa P, Bradley H, Hughes GD. (2006). Socio-cultural factors influencing food consumption patterns in the black African population in an urban township in South Africa. *Hum Ecol*, 14: 89-93.

Puoane T, Steyn K, Bradshaw D, Laubscher R, Fourie J, Lambert V, Mbananga N. (2002). Obesity in South Africa: The South African Demographic and Health Survey. *Obes Res*, 10:1038–1048.

Reddy SP, Panday S, Swart D, Jinabhai CC, Amosun SL, James S, Monyeki KD, Stevens G, Morejele N, Kambaran NS, Omardien RG and Van den Borne HW. (2003). *Umthenthe Uhlaba Usamila – The South African Youth Risk Behaviour Survey 2002*. Cape Town: South African Medical Research Council.

Sliwa K, Wilkinson D, Hansen C, Ntyintyane L, Tibazarwa K, Becker A, Stewart S. Spectrum of heart disease and risk factors in a black urban population in

South Africa (the Heart of Soweto Study): a cohort study. *Lancet*. 2008; 371: 915-922.

Statistics South Africa. (2002). Cause of Death in South Africa 1997–2001: Advance Release of Records of Death. Statistics South Africa: Pretoria, pp 18–42.

Steyn K, Fourie J, Bradshaw D. (1992). The impact of chronic diseases of lifestyle and their major risk factors on mortality in South Africa. *S Afr Med J*, 82**:**227–231.

Twagirumukiza M, De Bacquerb D, Kips JG, de Backer G, Vander Stichele R, Van Bortel LM. (2011). Current and projected prevalence of arterial hypertension in sub-Saharan Africa by sex, age and habitat: an estimate from population studies. *J Hypertens*, 29: 1243-1252.

Van Den Ende C, Twisk JW, Monyeki KD. (2014). The relationship between body mass index and dietary intake of primary school children from rural area of South Africa: The Ellisras longitudinal study. *Am J Hum Biol*, 26:701-706.

Van Lenthe FJ, Kemper HCG, Van Mechelen W, Twisk JWR. (1996). Development and tracking of central patterns of subcutaneous fat in adolescence and adulthood: The Amsterdam Growth and Health Study. *J Epidemiol,* 25: 1162-1171.

APPENDIXES

APPENDIX A (DATA FORM)

					DD	MM	YY
Subject number:		Birth Date:		observdate:			

Birth Date: DD MM YY; observdate: DD MM YY

Gender___M/F

ANTHROPOMETRY AND BLOOD PRESSURE DATA FORM

Weight (kg)			
Height (cm)			
Sitting height (cm)			
Mid-upper arm circumference (cm)			
Neck circumference (cm)			
Systolic blood pressure (mmHg)			
Diastolic blood pressure (mmHg)			

APPENDIX B (CONSENT FORM)

UNIVERSITY OF LIMPOPO

Faculty of Science and Agriculture

Department of Physiology and Environmental Health

Private Bag x 1106
Sovenga
0727
SOUTH AFRICA
Tel: (015) 268 2953
Email: Kotsedi.monyeki@ul.ac.za
Website:www.ul.ac.za

TITLE: **TRACKING DETERMINANTS AND RISK FACTORS OF NON-COMMUNICABLE DISEASES AMONG RURAL SOUTH AFRICAN POPULATION OVER TIME: ELLISRAS LONGITUDINAL STUDY**

INFORMED CONSENT FORM

Ellisras Longitudinal Study subjects will be requested to take part. This research is looking at the adolescents' and young adults' lifestyle risk factors and how they may affect the development of non communicable diseases, including obesity, hypertension, diabetes, coronary heart disease. If you agree to participate, you will be asked about what and how much you eat, your physical activity levels, the illnesses you or your family members may have had and your use of healthcare services and the type of support you receive from those around you. We will also ask you some questions about the number of people in your household, their ages, jobs, how much money you make or earn, some of the things that your household members may own and some of the hygiene practices that are followed in your household. We will also ask about your smoking patterns, alcohol intake, your use of drugs and your social and personal characteristics. We will measure your weight, height, arm and leg circumferences, arm and leg breadths, body fat measures along your arms and legs, your blood pressure and heart activity.

After an overnight 10 hour fast (where you do not eat or drink anything except water after your evening meal, the night before the blood sampling, and miss your breakfast the day of the test), we will place a sterile little tube in a vein in your arm and take 15 mls (3 teaspoons) of blood from this. We will give you a cup of sugar water to drink and then we will take two more blood samples (each 2 teaspoons) over the next two hours. Taking the blood sample may cause a little discomfort at the site but there are no risks for this test, other than those associated with routine blood sampling. All procedures will be supervised and carried out by appropriately trained medical personnel who will use techniques to minimise any risks of infection. This test is used routinely for medical purposes. The blood sample will be used to determine your blood sugar, insulin, cholesterol and other additional factors that may help us learn more about diabetes and cardiovascular diseases risk factors. In addition you will be required to provide 24 hour urine which will help to assess sodium, potassium and other electrolyte in the body. This will provide us with valuable information regarding your hypertension status. You will be required to wear an accelerometer for nine consecutive days which will be used to assess your physical activity.

These measurements and interviews will take place once every two years from 2013 to 2017 (2013, 2015 & 2017).

Questions about what foods you eat and alcohol and drug use, about household or family members, how much money household members make or earn in a month and some of the things that household members may own and your living conditions will be done in your home and will take no more than 120 minutes (2 hours). All the remaining interviews and assessments will take place at a nearby school and will last no more than 180 minutes (3 hours).

RISKS

Choosing to be part of this study or not to part of this study will not affect your ability to get care at health if you should need them. You may feel uncomfortable when being measured or when providing all the information asked or when your blood sample is collected; however, the examiners and interviewers will make every effort to make you as comfortable as possible during the process.

BENEFITS

There are no benefits to you as a participant; however, your participation will help provide ideas and information about the health status and healthcare needs among adolescents and young adults in this area and will contribute to understanding the health status and health care needs of adolescents and young adults in Africa. You will not be paid for taking part.

CONFIDENTIALITY- Any information obtained during this study will remain secret and kept safe private and will only be shared with your permission or as required by law. Participants will be given a number instead of using their names in the study, so they cannot be identified. The hard copies of the data will be safely discarded after data entry and cleaning. The electronic version of the data will be kept under locked storage in the principal investigators office.

PARTICIPATION- You can chose to be in this study or not. Your participation is voluntary, and you may get out of the study at any time and for any reason. Being or not being in this study does not cost anything. You can also refuse participate in any parts of the study and still remain in the study. The researcher may remove you from the study if conditions arise and give reason to do so. If you participate in the study, you will receive a small amount of money to help cover some of the travel costs you may have incurred during the research study.

CONTACT-This research is being done by Prof. Kotsedi Daniel Monyeki, Physiology Department, University of Limpopo. He may be reached at the local research office and can also be reached at (015) 268 2953 for questions or to report a research-related problem. You may contact Chairman of Ethics Committee Human Ethics Committee) - at (012) 521 4414 if you have questions or comments regarding your rights as a participant in the research.

This research has been reviewed according to University of Limpopo, ethics committee procedures governing your participation in this research.

CONSENT
PART:A:(To be used by adults and fully conscious persons):

I (NAME IN FULL)…………………………………………………….have understood the information I have been given/ I have read.

I, ………………………………………………….. agree to take part in the study.

Signature……………………………………………..Date ………………………………………………...

Witness
(NAME)..……..……………………………………………Signature……………………………………………
…Date…………………………………………

PART:B: (To be used by parents/guardians of children OR guardians, parents or relatives of patients with altered level of consciousness/ altered ability to consent):

I (NAME IN FULL)…………………………………………………….have understood the information I have been given/ I have read.

I, ……………………………………………….on behalf of ……………………………………………….. agree that he/she will to take part in the study

Reason of failure of (Name)……………………………………….. to consent is (TICK):

(i) Child ( )

(ii) Altered consciousness ( )

(iii) Others (specify)……………………………………………

Signature of parent/ guardian/ relative…………………………………………..

Mention your relationship with the participant……………………………………

Date ………………………………………………...

Witness (NAME)………..……………………………………………

Signature……………………………………………

Date…………………………………………………

Assent form for the child: I (NAME IN FULL)…………………………………………………have understood the information I have been given/ I have read.

I, ………………………………………………….. agree to take part in the study.

Signature……………………………………………..Date ………………………………………………...

APPENDIX C (ELLISRAS CUMMUNITY LETTER)

UNIVERSITY OF LIMPOPO

Faculty of Science and Agriculture

Department of Physiology and Environmental Health

Private Bag x 1106
Sovenga
0727
SOUTH AFRICA
Tel: (015) 268 2953
Email: Kotsedi.monyeki@ul.ac.za
Website:www.ul.ac.za

29 October 2015

The Principal/Manager

……

……..

……

Dear Sir/Madam

ALL ELLISRAS LONGITUDINAL STUDY MEMBERS ARE KINDLY REQUESTED TO TAKE PART DURING THE PERIOD NOVEMBER 2015 TO 5 JANUARY 2016

Diabetes, high blood pressure and cholesterol problems or high fat levels in the blood seem to be more common in the community than they were 10 or 20 years ago. This is most likely a result of both environmental and genetic factors. Environmental factors are those factors related to your lifestyle such as your diet and your physical activity levels. Genetic factors are those factors you "inherit" from your parents and grandparents. These conditions can lead to further health problems such as problems with eyesight, the heart and strokes, but the chance of having these problems can be lessened by treatment. It is my pleasure to report that the department of Physiology and Environmental Health, University of Limpopo will commence with the Ellisras Longitudinal Study (ELS) shortly. The aim of the ELS will be to track the role of lifestyle risk factors in determining adverse health outcomes. In particular, the development of non-communicable diseases, including obesity, hypertension, diabetes and coronary heart disease in a cohort of rural adolescents of South Africa over time.

All Ellisras Longitudinal Study subjects will be requested to take part. This research is looking at the adolescents' and young adults' lifestyle risk factors and how they may affect the development of non communicable diseases, including obesity, hypertension, diabetes, coronary heart disease. If you agree to participate, you will be asked about what and how much you eaten the previous day. Anthropometric measurements will include weight, height, sitting height, leg length, skinfolds: (triceps, biceps, subscapular and supraspinale), girth (waist, hip, arm girth flexed and tense, neck, arm girth relax and calf girth), width: (femure and humerus). Your blood pressure and pulse rate will be measured.

Furthermore, after an overnight 10 hour fast (where you do not eat or drink anything except water after your evening meal, the night before) we will place a sterile little tube in a vein in your arm and take 15 mls (3 teaspoons) of blood. Taking the blood sample may cause a little discomfort at the site but there are no risks for this test, other than those associated with routine blood sampling. All procedures will be supervised and carried out by appropriately trained medical personnel from University of Limpopo, Medical Research Council, Vrije University Amsterdam, The Netherland le Sefako Makgatho Health Science University, who will use techniques to minimise any risks of infection. This test is used routinely for medical purposes. The blood sample will be used to determine your blood sugar, insulin, cholesterol and other additional factors that may help us learn more about diabetes and cardiovascular diseases risk factors.

These measurements and interviews will take place during the period November 2015 to 5 January 2016.

Please allow me to refer to PhD thesis of Monyeki (2000):

"…Bahlalerwa (cultural name of our population) I requested for your help and you responded positively. I am happy because together we could make a difference. I am appealing to all of us to support and avail ourselves to any form of research activities taking place in our area. Such activities are geared towards improving the health not only of the Bahlalerwa population but the whole South Africa if not Africa. We should keep focus and if somehow we could be blinded, with the help of the Almighty God the father of Jesus Christ, crystals like glass will fall from our eyes like what happen to Paul in the Holy Bible. Our vision will be broaden and we will no longer think and perform our duties inside the box…."

Past my regards to everybody at home.

Yours sincerely

Prof Kotsedi Daniel Monyeki
Principal Investigator: Ellisras Longitudinal Study

Dr Marlise van Staden
Head of Department

PEER REVIEWED ARTICLES EMANATING FROM THE DISSERTATION

1. Ramoshaba NE, Monyeki KD, Zatu MC, Hay L and Mabata LR. (2015).The relationship between blood pressure and anthropometric indicators in rural South African children: Ellisras Longitudinal Study. *J Obes Weight Loss Ther*, 5:1.

2. Ramoshaba NE, Monyeki KD, Hay L. (2016). Components of height and blood pressure among Ellisras rural children: Ellisras Longitudinal Study. IJERPH,13: 856.