ASSOCIATION BETWEEN INFANT NUTRITION AND LATER BODY COMPOSITION

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DECLARATION

I, Juliana Kagura, declare that this research report is my own work, except where assistance has been acknowledged. It is being submitted for the degree of Master of Science in Medicine in the branch of Child Health in the University of Witwatersrand, Johannesburg. It has not been previously submitted for any degree or examination at this or any other Department or University. The study was approved by the Committee on Research in Human Subjects of the University of the Witwatersrand (M090420)

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ABSTRACT

Background: The long term effect of infant nutrition on later body composition has gained global attention since the developmental origins of health and disease because of the association between early life outcomes and later adult health (1). Under-nutrition and growth faltering during prenatal and infant periods have been reported to be related to subsequent growth faltering, high fat mass, and low lean and bone mass. Early life nutritional environmental cues may cause permanent effects on the physiology, metabolic and endocrine system of the body.

Objective: We investigated the association of infant nutrition and anthropometry with subsequent child anthropometry and body composition at age 9/10 years.

Design: This study comprised of 140 children who had infant growth measures and dual-energy X-ray absorptiometry (DXA) conducted at age 9/10 years. They were selected from the Bone health sub-study of 408 black children of the Birth-Twenty longitudinal study cohort comprising of children born in Soweto, Johannesburg in 1990.

Data collection and analysis: Data was collected on following variables; infant feeding, socio-economic status at delivery, anthropometry (birth weight, height and weight at ages 1, 2, 9/10 years). Body composition data was obtained from DXA scans. Food frequencies questionnaires were used for dietary patterns data collection. Data cleaning and analysis of data which encompassed descriptive, bivariate and multivariate analyses were done in STATA 10 and the 5% level of significance was used for statistical significance.

Results: Children were breast-fed on average for 13 months in boys and 16 months in girls ($p=0.009$) while those bottle fed had a duration of 10 months for both sexes. Introduction of solid foods was around 3 months while the approximate mean dietary diversity score (the number of food groups consumed by an infant in a 24-hour recall period) was 1 and the food

variety score (the number of food items consumed by an infant in a 24-hour recall period) was 2 for both girls and boys. Prevalence of stunting, wasting and underweight at 1 year was 8.6%, 3.6% and 8.6% respectively. At age 2 years, the prevalence was 15.7%, 8.6% and 16.4% for stunting, wasting and underweight, respectively.

All the associations between infant nutrition variables and subsequent growth and body composition at age 9/10 years were statistically non-significant. In the multivariate model, increase in birth weight predicted an increase in weight and height at ages 1, 2 and 9/10 years, lean mass (β=0.20, CI=0.01-0.03, p=0.007), radius (β=0.02, CI=0.00-0.04, p=0.039) and lumbar spine (β=0.03, CI=0.01-0.05, p=0.018). Infant weight and height at 1 year were significantly positively associated with subsequent growth at 2 and 9/10 years and with body composition variables.

Stunting at age 1 year was significantly associated with lower fat mass (β= -0.18, CI= -0.03 to -0.06, p=0.003) while stunting at age 2 years predicted lower fat only (β= -0.12, CI= -0.22 to -0.03, p=0.011) after adjusting for confounders. Being underweight at age 2 years predicted lower fat mass in the multivariate model.

Conclusion: Infant nutrition had no significant influence on subsequent growth and body composition. Birth weight and infant anthropometry; particularly height, weight, stunting and underweight are the main predictors of body composition at age 9/10 years. There is need for promotion of optimal prenatal and infant growth in children to reduce risk of chronic diseases like Type 2 diabetes, hypertension and osteoporosis in later life.

DEDICATION

To Felix, my husband and best friend: You have been a true inspiration.

To Tinotenda, my son: You gave me space to study.

To Theresa, my mother: For investing all you had for a girl-child against all odds.

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CHAPTER ONE: INTRODUCTION

This chapter comprises of the background of the study, problem identification, the aim of study, research question and review of literature. It also includes the objectives and the hypotheses of the study.

1.1 Background

Childhood malnutrition flourishes during periods of vulnerability, usually from prenatal life to two years. This is a critical period where intervention can be effective at short and long-term levels. Nutrition in early life has become a global priority in the light of its long term effects on health (2). Appropriate nutrition in early life is very important for optimal growth and development, starting from the cell, and continuing into tissue, organ and whole body growth and development.

Early life is a period of high vulnerability for humans in harsh environments that influence their growth, nutritional status and body composition outcomes in later life (3). Increasing evidence implicates early nutrition as an important factor for "programming" body composition through foetal and postnatal growth (4;5). Body composition, in turn, is linked to the development of chronic and metabolic non-communicable diseases such as osteoporosis, type 2 diabetes mellitus, cardiovascular diseases, metabolic syndrome, hypertension and certain forms of cancer (6).

Prenatal malnutrition leading to poor birth outcomes like low birth weight followed by early postnatal malnutrition can be a risk factor for obesity and other related non-communicable diseases in later life. Several epidemiological and clinical studies have suggested that there is an association of prenatal and early postnatal nutritional environment with postnatal growth (7;8) and later body composition (9). The framework on Figure 1 outlines the possible

pathway through which early life nutrition can program body composition and disease risk in later life.

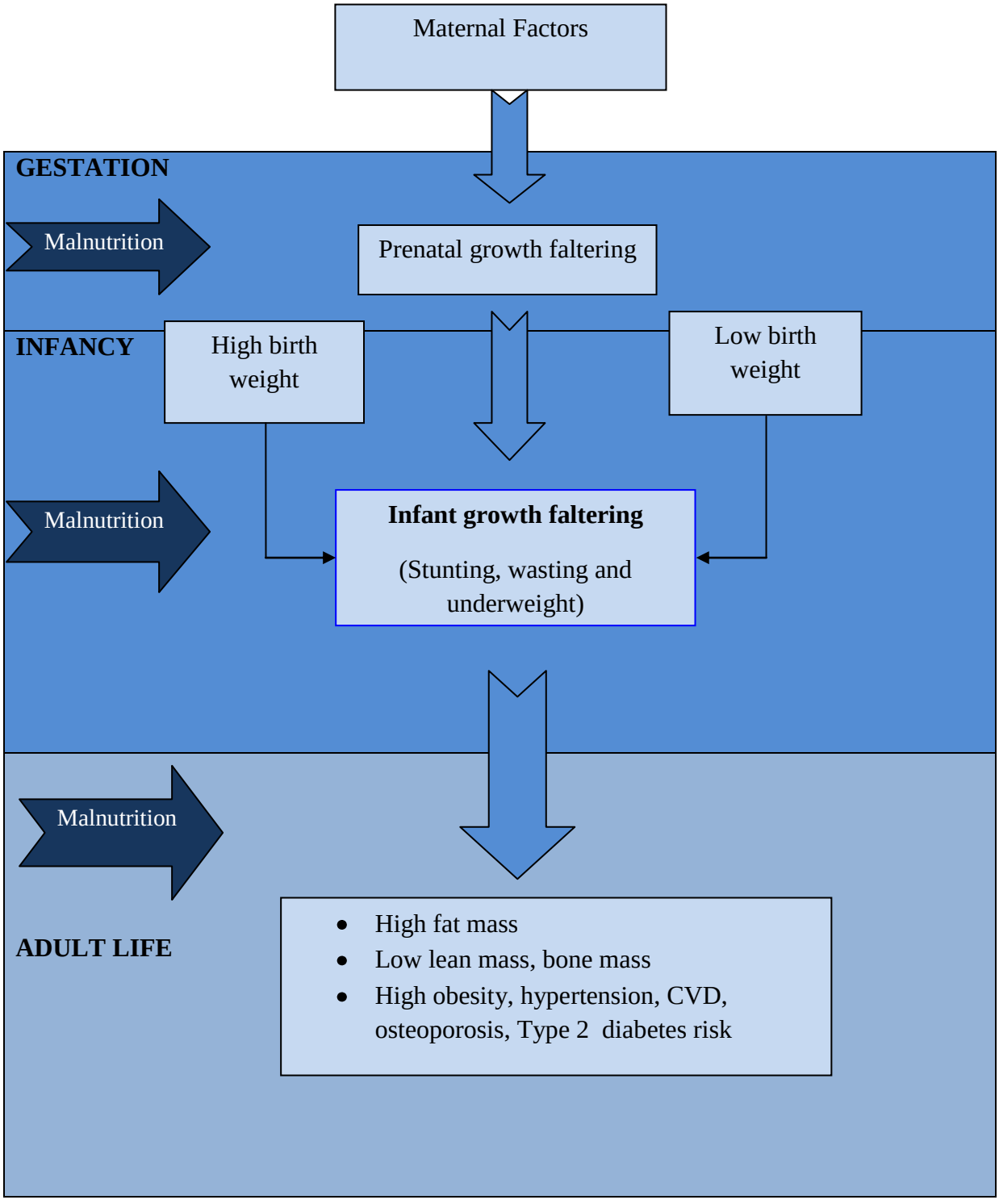


Figure 1: Possible pathways of nutrition programming

Adopted from (10;11)

1.2 Problem Statement

Child malnutrition remains a global burden with an annual estimated 112 million children under age five years being underweight and 178 million stunted (12). In developing countries, it is estimated that 195 million of children under five years are stunted, 26 million are wasted and 129 million are moderately or severely underweight. Of these, it is estimated that around 90% are in Africa and Asia (13). In Sub-Sahara Africa, the battle for an African child to survive is intense due to the socio-economic and political environment, with the high HIV/AIDS prevalence adding the burden onto the nutritional status of children, especially in the first two years of life. In 2006, southern Africa had an estimated 41% stunting, 23% underweight, 6% wasting for children aged under five years and estimated 12% low birth weight in this region (14) .

South Africa is classified as a low-to-middle-income country (LMC) undergoing a dramatic socio-economic and political transition since 1990, which caused an influx of the black population from the rural areas into urban areas in search of jobs and an end to rural poverty. These changes are reflected in nutritional outcomes, for example physical changes like stature and body composition, which are strong indicators of nutritional transition (15). In these urban areas, poor households are at risk and under-nutrition in early childhood often coexists with over-nutrition and related chronic diseases across all age groups (16;17). The South African Vitamin A Consultative Group (SAVACG) study conducted in 1995 reported a national estimation of underweight (9.3%), stunting (22.9%) and wasting (2.6%) in children aged 6-71 months. An international obesity task force also reported a combined overweight and obesity percentage of 24.7 in urban areas and 19.0 in rural areas with the informal urban being at 19.3% (18;19). South Africans therefore face a cascading burden of disease, from infectious diseases like HIV/AIDS and swine flu to nutrition-related non-communicable diseases (NR-NCDs) and poverty-related hunger.

Despite the relevance of tracking early life predictors of subsequent body composition in developing countries, such tracking efforts have been limited by lack of funds to support birth longitudinal cohorts. However, in South Africa, the Birth to Twenty longitudinal birth cohort allows researchers to track these associations in a socio-economically and politically ever-changing environment.

1.3 Aim of the study

To investigate the association between birth weight, infant nutrition and anthropometry with body composition at 9/10 years of age.

1.4 Research question

Is there any association between birth weight, infant nutrition and anthropometry with body composition at 9/10 years of age?

1.5 Literature Review

This review summarises the evidence of early life factors associated with pre-pubertal body composition, potential confounders, definition of body composition in context to the assessment method employed in this study and previous literature citing the associations between the early life variables and later body composition.

1.5.1 Infant nutrition

In infancy, feeding practices have a greater impact on the nutritional status of children since they solely depend on milk to meet all of their nutritional requirements. This is especially in the first six months of life as their digestive systems are highly sensitive and are able to adapt to environmental cues. After weaning, it is vital that the child's diet provides all essential minerals, energy, micronutrients and vitamins necessary for growth. Rapid growth and development at this period puts a high demand on nutrition. Growth faltering at this stage is therefore mainly dependent on feeding practices and complementary feeding (20;21).

1.5.1.1 Breastfeeding

Breast milk supplies essential nutrients to meet the demand for rapid growth and development for at least the first six months in normal infants (WHO, 2002). Human milk contains a variety of bioactive materials such as immunoglobulins, enzymes, growth factors (i.e. leptons, insulin-like growth factor-1, adiponectin) and hormones that have the potential to regulate the metabolism, energy intake and appetite of the infant (22). These materials influence the physiological and metabolic pathways, affecting body fat levels and weight gain patterns (23). In addition, breast milk contains high levels of cholesterol and essential fatty acids like linoleic acid which are not found in formula milk. These are easily hydrolysed into beta-monoglycerides, which are more easily absorbed than alpha-monoglycerides (a by-product of hydrolysis of fats in cow milk), which may reduce risk of obesity in later life (24).

1.5.1.2 Bottle feeding

Bottle feeding in developing countries like South Africa is a growing practice despite high risk of infection due to poor sanitation, especially in low income groups. The preparation and sterilisation process is tedious and often compromises the sanitary conditions, which in turn might cause diarrhea and gastrointestinal infections. This has been reported to be the reason for growth faltering in bottle-fed infants (25).

1.5.1.3 Complementary feeding

Appropriate complementary feeding has to be timely, nutritionally adequate and should comprise of appropriate food to complement breast milk. The age at which complementary feeding commences in infants has been of major concern, especially in the developing countries, mainly due to risk of infections during food preparation and failure of the gastrointestinal tract to adjust to solids (26). From 6 months, the gastrointestinal tract of an infant should have matured enough to take other foods in addition to milk to meet the higher nutritional demand of the growing infant (27). The other important attribute of

complementary feeding is dietary variety. This is very vital for enhancing the micronutrient intake in infants to meet all the nutritional requirements for growth.

1.5.1.4 Dietary patterns

Dietary diversity and food variety is a key component in most dietary guidelines to ensure adequate intake of essential nutrients and promotion of optimal health in infancy after weaning. Dietary diversity has been reported to be associated to certain indices of nutritional status in infancy like stunting, especially in developing countries (28;29). Therefore, it is essential to evaluate indicators of dietary diversity such as dietary diversity and food variety scores as measures of nutrient adequacy in infants.

1.5.1.5 Infant anthropometry

Infant anthropometry has been widely used as a nutrition assessment tool and anthropometric measurements are useful in the evaluation of the nutritional status in children. These involve the measurements of physical dimensions such as height and weight. This method can be used to determine the degree of nutrition. It is cheaper and easier to perform and is a useful tool to monitor growth in children (30). Physical growth is the increase in the mass of the body tissues and is measured in terms of body size, length and head circumference in infants. Height is a main indicator of linear growth and weight estimates the mass of all body tissues. An infant is considered stunted, underweight or wasted if their height-for-age, weight-for-age or weight-for-height z-score is less than -2, respectively. Severe under-nutrition corresponds to z scores less than -3 (31).

1.5.2 Body composition

Body composition is a term used to describe different body components which make up body weight. The human body consists of two major components which are fat mass and fat free mass. Fat free mass is non-adipose, metabolically active and extremely homogenous. It

comprises of bone and lean mass (i.e. muscle, extra cellular water, nervous tissue and various organs and all non-adipose cells) (32).

1.5.2.1 Fat mass

Fat mass is a component of the human body classified into two forms; storage fat and essential fat. The storage fat is the body fat stored in the adipose tissue and the major stores are subcutaneous and under the skin, in the abdomen and around delicate organs such as the heart. It is metabolically inactive and a risk factor for obesity. Essential fat is stored in the bone marrow, delicate organs and the nervous system and is more metabolically active than storage fat (33).

1.5.2.2 Lean mass

Lean mass mainly comprises of muscle, organs, nervous tissue, cells and water. Poor organogenesis and cell growth results in ultimate low lean mass. Lean mass is proportional to body stature; the taller the child, the greater is the amount of muscle mass (34).

1.5.2.3 Bone mass

Bone mass comprises of an inorganic matrix, primarily calcium and phosphorus reserves, and an organic matrix made up of mainly collagen fibres and other proteins. The bone tissue consists of cortical tissue and trabecular tissue. Calcium levels in the bone are under homeostatic regulation by calcium-regulating hormones. This system is more efficient in early life and decreases after skeletal maturity (35).

Skeletal growth is most rapid in early life in bone modeling, where the long bones elongate and widen, resulting in an increase in bone mass. Adolescent spurts are marked by a steady bone growth which slows down before diminishing at early adulthood. The skeleton therefore reflects the growth of an individual from intrauterine life through the years of growth into early adulthood when the peak bone mass is attained. The framework in Figure 2

shows that although bone accretion is mainly under genetic control, full genetic potential of the bone accrual can be compromised significantly by early life environmental factors like nutrition, where the rate of accrual is greatest, leading to increased fracture risk in later life (36).

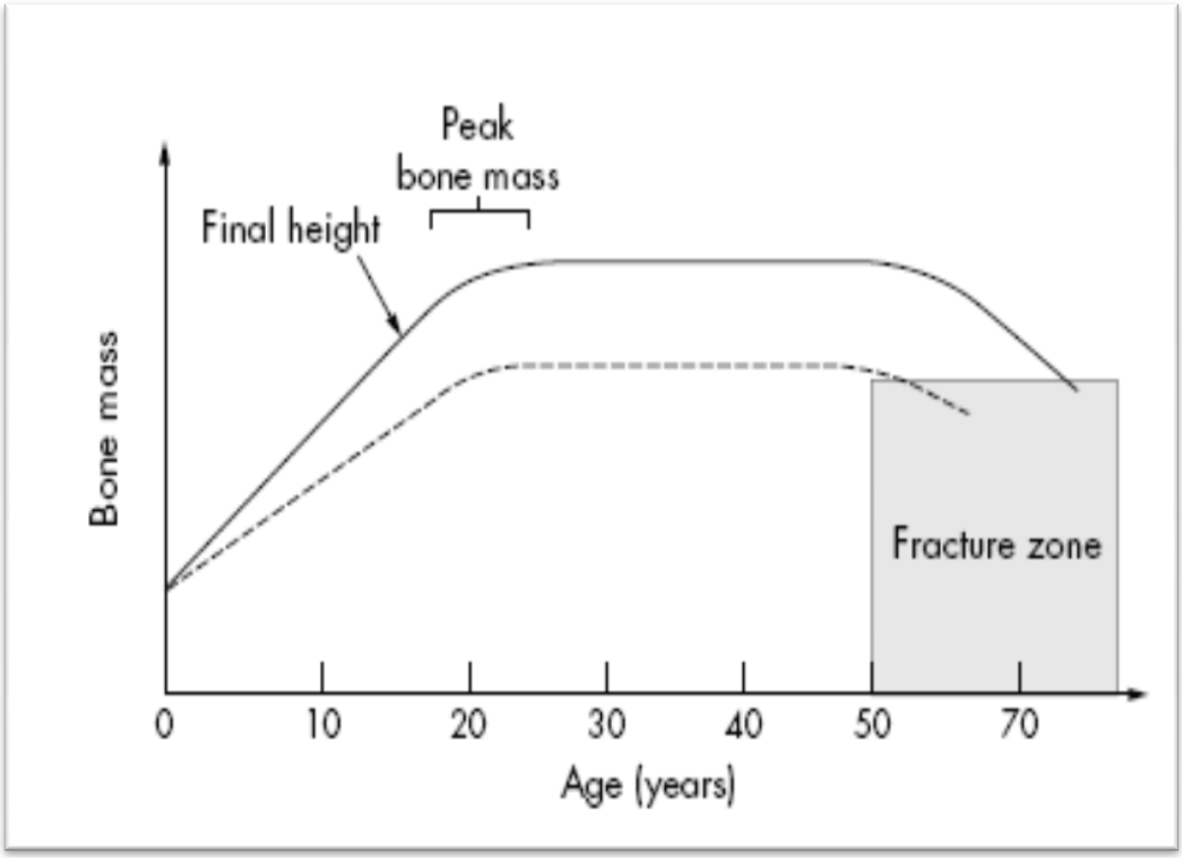


Figure 2: Bone mass accretion with age

Adopted from (36)

1.5.3 Association between infant nutrition and later body composition

Early life is a period where humans are highly plastic and able to adapt to malnutrition. Rickets serves as an example that malnutrition in early life can leave a permanent long-term effect on the body. Several hypotheses have been increasingly used to support nutrition programming of body composition. These include "foetal origins" (37), "predictive

adaptive" (38) and the "developmental origins of disease hypothesis" (DOHaD) (1). These hypotheses support the notion that a single genome produces more than one alternative form in terms of its structural, morphological and physiological state in response to environmental cues which an organism is exposed to during critical windows of development followed by loss of plasticity and a fixed functional capacity. These plastic responses in early life are capable of imprinting permanent and long-term modifications on the morphology and physiology of a human body to fit the forecasted environment, but may have adverse effects if there is an environmental mismatch in later life (39). These hypotheses have been tested in both animal and human studies and have produced inconsistent results due to differing study designs and confounding.

1.5.3.1 Mechanism of nutrition programming

The concept of nutrition programming was postulated by Lucas (40) and Desai and colleagues (41), suggesting that programming takes place at the cell, gene and endocrine levels.

Cellular level

Undernutrition in early life can lead to impaired cell replication, resulting in a reduction in cell numbers, reduced cell sizes, reduced organ size or tissue sensitivity to certain hormones. This reduces cell activity, capacity and functionality. Hales and Barker (42) reported that malfunctioning of the beta cells of the pancreas was associated with low birth weight, implicating intrauterine under-nutrition. Ultimately, reduced cell numbers limit the body size of an individual and growth-retarded babies have been reported to have reduced cell numbers in their organ. This can be linked to limitations in organ function.

Gene expression level

Permanent alteration of genes to adapt to environmental cues at critical periods of development can affect methylation or histone acetylation of DNA during transcription, affecting expression of various genes involved in synthesis of critical metabolic and structural proteins like hormones, enzymes and collagen. Epigenetic gene regulation has been reported to be a link between early nutrition and later chronic disease risk (43). This mechanism has been used to support the thrifty phenotype hypothesis which is a phenomenon whereby one genotype can be expressed in different forms in a phenotype in response to the environmental conditions which the organism is exposed to during periods of developmental plasticity (44). The essence of this hypothesis is that in a dynamic environment, it maximises diversity and enables the production of phenotypes that are more suited to the environment forecast. However, the disadvantage comes when the environment change after functional capacity is fixed and plasticity has been lost (45).

Endocrine system level

The endocrine system can be programmed in early life by nutrition resulting in alteration of metabolic pathways to suit the nutrition environment. Desai and colleagues reported that adult glucose metabolism may be programmed in early life (46). Hypothalamic-pituitary-adrenal axis is programmed in early life in response to levels of nutrition. This in turn resets the fat, glucose and protein metabolic pathways involved in controlling body composition and functionality of the growth hormone (47).

1.5.3.2 Feeding practices and later body composition

Breastfeeding is associated with slower infant growth and lower fat mass in later life. This has been reported as another advantage to a longer duration of breastfeeding (48). The association between breastfeeding and later bone mass or fat mass is not yet fully known due to many confounders and problems around study designs in longitudinal studies. The impact

of breastfeeding on later adiposity and bone mass has been recently reported in several studies (49-51). However, Jones et al. (52) reported that eight year old children who were breastfed had a higher bone mineral density at the femoral neck, lumbar spine and the whole body compared to the formula fed infants. Human milk also contains a growth factor which is known to inhibit adipocyte differentiation (53), giving breastfeeding a protective effect against obesity.

1.5.3.3 Complementary feeding and body composition

Inappropriate complementary feeding practices may have a long term negative impact on health through two mechanisms. One is the cumulative effect of physiological changes which, while staring in early life, results in clinical evidence of morbidity years later and secondly, the creation of food habits leading to undesirable dietary practices, which trigger health problems like obesity. Early introduction of other foods to supplement milk may have long-term undesirable effects including a risk of obesity, hypertension, arteriosclerosis and food allergy due to morphological and physiological responses by the delicate infant system which might temporarily or permanently alter the endocrine, metabolic systems and organ functionality (54).

1.5.3.4 Dietary patterns and later body composition

Dietary diversity in a weaning diet may be associated with certain nutrition status indicators like stunting in infants and body composition in later life. Several studies have reported the association between dietary diversity scores and height-age z-scores (28;29). Therefore, there is need to explore the association between dietary diversity in weaning diet and subsequent body composition.

1.5.3.5 Infant anthropometry and later body composition

Growth in early life is associated with subsequent body size and composition. Growth faltering at critical periods may also leave long-term effects on body composition. Several epidemiological studies in developed countries have reported an association between postnatal growth and later body composition (55-57). In developing countries, infant weight gain was reported to be associated with later weight, height and lean mass but not with later fat mass (58;59). Stunting in infancy has been reported to be associated with gaining more of fat mass than lean mass in Brazil (60). There is need to explore the association between growth indices related to malnutrition like stunting, wasting and underweight, and subsequent body composition in a developing country scenario in Africa from a longitudinal cohort study.

1.5.4 Factors mediating programming of body composition

1.5.4.1 Prenatal nutrition

Prenatal nutrition plays an important role in foetal growth and development and any nutritional disruptions during the critical period of gestation may leave a permanent "memory" throughout life. There is growing evidence that maternal nutritional status may alter the epigenetic state of the foetal genome and imprint gene expression (61). Birth weight is often used as an index of prenatal nutrition and growth (62). Body size and composition at birth largely reflects the supply of nutrients and oxygen to the growing fetus. Birth weight has been reported to be associated with bone mineral content (63) and lean mass (64), but inconsistently with fat mass (65). Birth weight also is under the influence of the prenatal environment like certain indices of socio-economic status.

1.5.4.2 Socio-economic status (SES)

SES is an important factor in the programming of body composition and diseases in children. It is associated with birth outcomes, malnutrition, stunting and child growth and all these determine the health outcomes in later life. A study carried out by Griffiths et al. (66) on children in South Africa enrolled in the Birth to Twenty study cohort found out that SES at birth had a stronger association with lean mass, while late childhood SES had a stronger association with fat mass. The authors also suggested that bone mineral content in black South African children was associated with SES at birth.

1.5.4.3 Gender

Sex-specific differences in growth and body composition variations in fat mass, lean mass, bone mineral content and average stature are mainly associated with hormonal differences in males and females (67). Total fat mass increases in both sexes. However, because there is a higher increase in fat-free mass and bone mineral content in boys than in girls and greater increase in fat mass in girls than boys, at the end of pubertal development, boys have approximately 1.5 times the fat-free mass as girls and half the percentage body fat (68).

1.6 Objectives of the study

The main objectives of this study:

1. To describe the association between birth weight and anthropometry at age 1, 2 and body composition at age 9/10 years?
2. To describe the relationship between infant nutrition and anthropometry at age 1, 2 and body composition at 9/10 years of age?
3. To assess the association between nutritional status (from anthropometry) in infancy (ages 1 and 2) and body composition at age 9/10?

1.7 Null hypotheses tested

A. There is no association between infant nutrition and later body composition.

B. There is no association between early life anthropometry at birth and in infancy and later body composition.

CHAPTER TWO: METHODOLOGY

2.0 Introduction

This chapter gives information on the study population setting, design and sample selection. It also presents the materials and procedures used in this study and comprehensive description of data collection and processing. It also describes the stages of statistical analysis and highlights the human ethics clearance for the study.

2.1 Study population setting

Soweto is located 40 kilometers from the centre of the city of Johannesburg and it comprises of a diversified economic, ethnic and social community. It was formally designed by the South African government to accommodate blacks who were working in gold mines in Johannesburg and those who had been forcedly removed from whites' designated areas. In the late 1980s, rapid urbanization began as a result of the crumbling apartheid system, leaving an influx of black South Africans into the cities disregarding the restrictive legislation. This rapid, unplanned urbanisation had profound effect on the infrastructure, health care services, education and employment in Soweto-Johannesburg (69).

2.2 Study design

Birth to Twenty (BT20) is the longest and largest running longitudinal birth cohort study in Africa tracking growth, health and development of South African children born in Soweto-Johannesburg. In late 1989, women in public antenatal clinics were interviewed in an effort to collect data from pregnant women who were predicted to deliver their babies during the enrolment period occurring from April 23 to June 8, 1990. Enrolment included singleton births of infants born in the Soweto-Johannesburg metropolitan area (n=5449) several months after Nelson Mandela was released from prison. Of all these infants, only 3275 met the

enrolment criteria of being born to mothers who were residents of the greater Johannesburg metropolitan area for at least the first six months of the participant's life (Richter et al., 1995).

BT20 started as birth to ten (BT10) with the broad collection of data during the antenatal period on pregnancy and birth, then on child growth, nutrition, health and development using the life-course approach. The second phase, leading to BT20, encompassed the exploration of early life risk factors like diet, physical activity, parental involvement, educational achievement, sexual behavior, physical (body composition), physiological (pubertal assessment, biochemical markers) measures and the bone health sub-study (70).

For the bone health sub-study, 340 black children were randomly selected from the BT10 study and 65 white children were included from the larger cohort as longitudinal data was available for them. Furthermore, 71 children who were born during the initial cohort enrolment dates from schools in the Greater Johannesburg area were invited to participate in the study retrospectively to increase the number of white participants (70). In total, the bone health (BH) study includes 214 black boys, 59 white boys, 194 black girls and 54 white girls.

Comprehensive sets of longitudinal prospective data is available and cross checks were performed to ensure that there were no significant differences between the BTT and the BH sub-sample for key demographic variables like residential area at birth, birth weight and gestational age.

2.2.1 Study sample selection

The study sample comprised of the black participants (n=140) from the bone health sub-study (n=408) who had DXA data at age 10 years (if not, age 9 years) (n=374), birth weight and infant growth data for ages 1 and 2 years (n=188) and infant feeding data (n=140).
Participants with chronic illnesses or on medication known to affect growth were excluded in

addition to those who did not have body composition data for age 9/10 years, infant growth data at ages 1 and 2 years of age and had no dietary data at age 1 year (Figure 3).

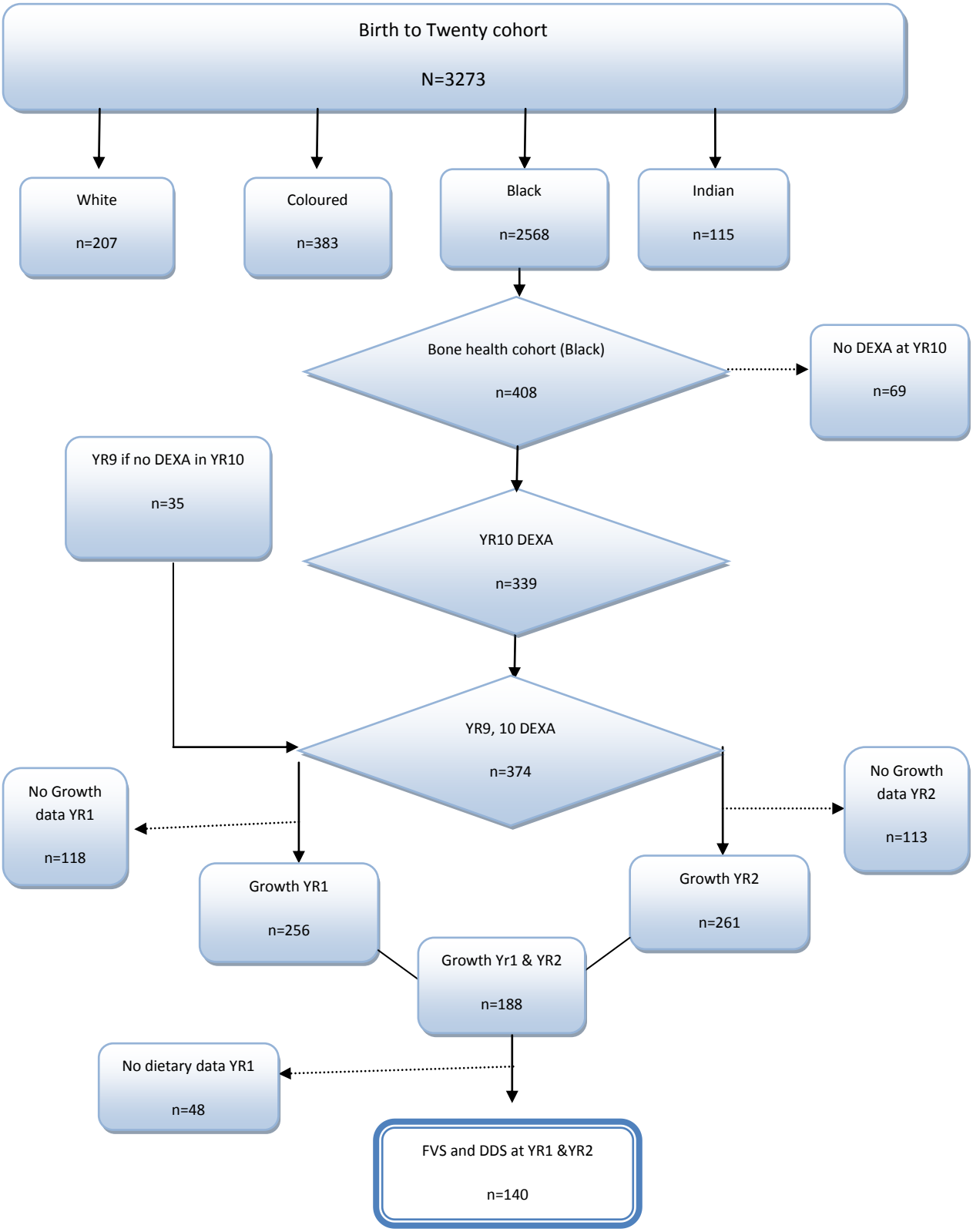


Figure 3: Study sample selection criteria

2.3 Materials and procedures

This study is based on the secondary data collected from birth to age 9/10 years depending on the variables under investigation. Infant feeding data was collected prospectively in the first twenty-four months by trained and experienced caregivers, and an unquantified food frequency questionnaire (FFQ) to assess dietary patterns (Appendix 1). This was administered retrospectively to assess the frequency of infant consumption of food items over a seven day period.

2.3.1 Household socio economic status at delivery

Primary caregivers answered questions about their social and economic status. The questionnaire was modified and validated to conform to the South African population and was based on standard measures used by Demographic and Health Surveys (DHS). The measures included marital status, maternal education and household environment (water source, house ownership, type of house and consumer durables like television, refrigerator, washing machine, and phone ownership).

2.3.2 Infant feeding data

Infant feeding data was collected and classified according to duration in months of breastfeeding, bottle feeding and month when solids were introduced. Exclusive breastfeeding referred to feeding the infant from the breast only. Introduction of solids was defined as feeding of solids and some semi solids in addition to milk feeding either breast or formula milk. Bottle feeding was defined as use of bottle to feed the infant.

2.3.3 Infant dietary patterns

Dietary patterns were assessed using the dietary diversity score (DDS) and the food variety score (FVS) to evaluate nutritional adequacy of the diet from a retrospective qualitative food

frequency questionnaire (FFQ). Caregivers of the one-year-old infants were interviewed by trained interviewers using a Food Frequency Questionnaire (FFQ) on a weekly recall period.

2.3.3.1 Dietary diversity score

The dietary diversity score (DDS) was defined as the number of food groups consumed by an infant in a 24-hour recall period (71). The 149 food items were classified into 11 categories using food groups recommended by Food and Agriculture Organisation (FAO). The DDS was calculated by dividing the weekly score by seven and stratifying values by gender in STATA using a t-test.

2.3.3.2 Food variety score

Food variety score was defined as the number of different food items consumed over a period 24 hours (72). Caregivers would indicate the infant's usual consumption from 149 food items and estimate the frequency of consumption in a day by dividing the values by seven to give a food variety score. Appendix 2 shows the 11 food groups and specific food items consumed as presented in the FFQ.

2.3.4 Infant and pre-pubertal anthropometry

Birth weight was measured at time of birth and data was collected from birth notification records of all birth registered in the municipal area under a local ordinance. These data have been previously validated during the BT10 pilot study stage (73).

Length at years 1 and 2 of age were measured with Harpenden tape by a trained research assistant to the nearest millimeter while weight at ages 1 and 2 were measured to the nearest completed 0.1 kg using a digital scale. These parameters were used to calculate z-scores using the WHO anthro version 3.1 software (74). The z-scores were put into categories

according to WHO guidelines. The infants were considered stunted, wasted or underweight if their height-for-age, weight-for-age or weight-for-height z-score were less than -2 (75).

Height at 10 years was measured using the stadiometer (Holtain, Crosswell, UK) and recorded to the nearest millimeter. Weight was measured using a digital scale (Dismed, USA) to the nearest 0.1 kg. Both instruments were regularly calibrated and participants wore light clothing and were barefooted.

2.3.5 Pre-pubertal body composition assessment

The Dual Energy X-ray Absorptiometry (DXA) was used to measure bone mass at the whole body, lumbar spine (L1-L4), non-dominant distal (1/3) radius and hip neck (femoral neck) according to standard procedures. A spine phantom was used for Quality Control to ensure precision of the machine. Bone mass was expressed as bone mineral content (BMC: g), the whole body scan from the DXA was used to assess whole body lean (fat-free mass) and fat tissue (g) using Hologic software, version 11.2 (Hologic, Waltham, Mass., USA) excluding the head.

The DXA has low levels of emitted radiation and require minimum cooperation from the patient thus making it user-friendly in paediatric research work. The scanning works by making use of a dual energy x-ray source which generates two x-rays which pass through the subject. The relative absorption at these two energies is measured to estimates of body composition allowing the beam path using a two component model. Fat and fat-free mass are estimated by attenuation, while the other attenuation gives a proportion of bone and soft tissue (76).

2.3.6 Pubertal assessment

Trained same-sex observers assessed pubertal development by using the Tanner scaling technique for breast, genitalia or pubic hair. Children were divided into two stages of development, namely, pre and early pubertal (Tanner stage 1 and 2) (77).

2.4 Statistical Analysis

The dataset obtained in a Microsoft access format was imported into STATA version 10 for use in all stages of analysis including data cleaning, descriptive and inferential analysis as summarized below.

2.4.1 Data cleaning

Data cleaning was the initial step carried out to check if the dataset contained all requested variables to screen outliers and inliers or any erroneous and duplicated data entry by doing consistency checks. Random selection of 10% of the bone health sub study data (n=521) for percentage error calculation yielded a 0.96% (n=5) error. These errors were corrected after checking with the questionnaires.

The framework in Figure 3 was a useful tool for data cleaning (78). After data cleaning, multiple values of certain variables were collapsed into discrete categories to increase ease of presentation and simplifying subsequent statistical analysis to evaluate the hypothesis in question. The variables were re-coded and labeled and the categories were defined in STATA.

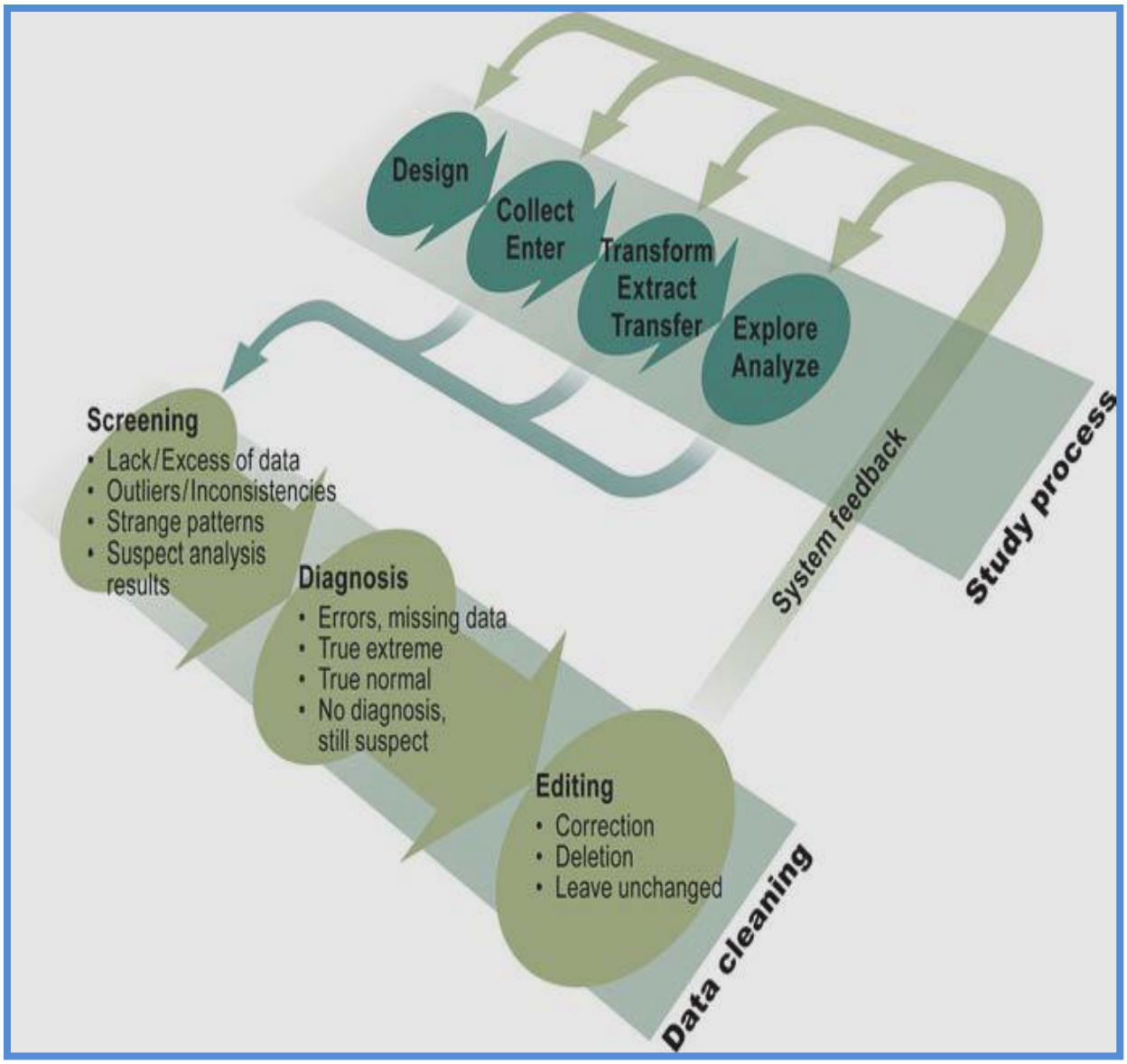


Figure 4: Data cleaning framework

2.4.2 Descriptive statistics

Summary descriptive statistics were used describe the basic features of the dataset for each variable. The continuous variables were summarized by gender in tables as number of observations, mean, standard deviation and p-values at a 5% level of significance using a t-test. Some of the variables were categorized, recoded, labeled and cross-tabulated to give proportions for each gender in percentages and frequencies plus the p-values using a Pearson's chi- square test. This test also was used to check selection bias of the study sample with respect to the entire bone health sub-study sample.

2.4.3 Inferential statistics

Normality tests were done to check for skew in the body composition outcome variables and the skewed data were log-transformed in STATA. Bivariate analysis also was conducted to check associations between the early life variables and body composition using linear regression. Linearity was tested by comparing fitted and predicted residuals for the independent variables. Multiple regressions were done to evaluate the association between the exposure variables and the outcome variables allowing for several confounders.

Confounders were those variables which were associated with the exposure as well as the outcome variable. Multiple logistic regressions were used for categorical growth variables like stunting, wasting and underweight and the odds ratio, confidence interval and p-values were reported. Multiple linear regressions were done on all models with continuous dependent variables and the co-efficient, confidence interval plus the p-values were tabulated.

The epidemiological flowchart in Figure 5 shows an overview of study variables used to test for associations between early life variables and pre-pubertal body composition allowing for several listed confounders. The descriptions of all the variables used in this study are provided in Appendix 4.

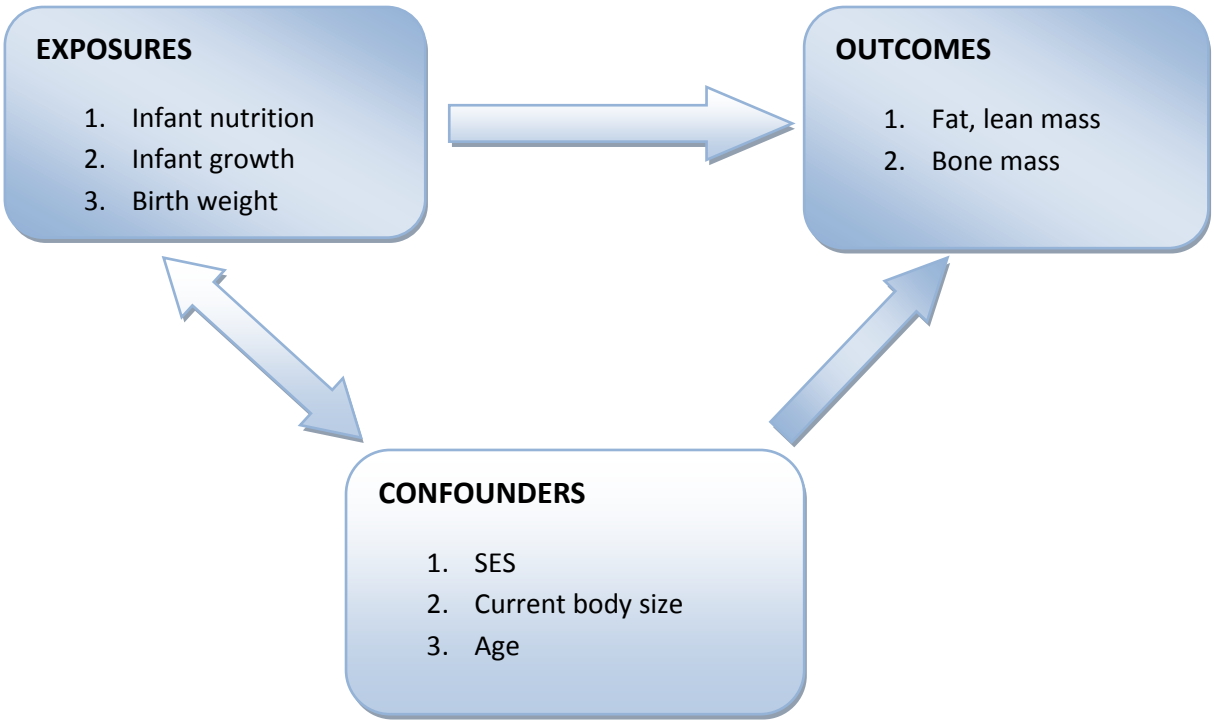


Figure 5: Epidemiological flow chart of study variables

2.5 Ethics clearance

This study obtained an ethics approval from the University of the Witwatersrand Ethics Review committee (Certificate no: M090420 in Appendix 3). The BT20 longitudinal study has ethical clearance from the Research Ethics Committee in South Africa. Informed consent was sort from the parents/caregivers at all points of data collection by a trained research assistant.

CHAPTER THREE: RESULTS

3.1 Introduction

This chapter describes all selected study variables and assessment results of selection bias of the study sample and sex differences in all the variables included in the study. Bivariate and multivariate analyses also were performed to test for associations before and after accounting for confounders, respectively.

3.2 Sample selection

From Figure 4, the study sample comprised of the 140 black participants who met the selection criteria from the Bone Health black participants (n=408). Those who met the selection criteria had the following: Age 10 DXA results (if not, age 9) (n=374), birth weight, infant growth data in age 1 and 2 (n=188) and dietary data (n=140).

To check whether the study sample was a true representation of the entire bone health black population, a comparison between those participants in the study sample and those in the rest of the bone health black participants was conducted using a Pearson's chi-square test on key demographic and selected childhood characteristics at birth. The results are shown in Table 1.

Table 1: Comparison between Bone Health black participants and those in the Study sample.

Variable	**Study sample Included(N=140) n(%)**	**BH Black excluded (N=268) n(%)**	**P-value**
Current maternal age			
13-18	31(22.1)	28(10.5)	**0.002***
19-29	82(68.6)	161(60.1)	
30+	27(19.3)	79(29.5)	
Gravidity			
1	64(45.7)	95(35.5)	**0.044***
2+	76(54.3)	173(64.6)	
Parity			
1	70(50.0)	103(38.4)	**0.025***
2+	70(50.0)	165(61.6)	

Gender			
Male	75(53.6)	139(51.9)	0.743
Female	65(46.4)	129(48.1)	
Marital status			
Married/living together	31(22.1)	72(26.9)	0.297
Single/divorced/widowed/separated	109(77.9)	196(73.1)	
Maternal education			
≤Std 8	17(12.1)	35(13.2)	0.761
≥Std 9	123(87.9)	230(86.8)	
Gestational age			
≤36	120(85.7)	233(86.9)	0.731
37+	20(14.3)	35(13.1)	
Birth weight			
≤2499g	16(11.4)	28(10.5)	0.491
2500-3999g	89(63.6)	184(69.3)	
4000g+	35(25.0)	54(20.3)	
House type			
Shack/flat/hostel/room/garage	10(7.1)	34(12.9)	0.078
House/cottage	130(92.9)	230(87.12)	
House ownership			
Other	49(35.0)	73(27.3)	0.126
Owned	91(65.0)	191(72.4)	
Water type			
Other	71(51.1)	124(48.3)	0.898
Indoor	68(49.0)	133(51.8)	
SES Water usage			
Shared	22(15.8)	40(15.6)	0.945
Sole usage	117(84.2)	217(84.4)	
Toilet usage			
Shared	22(15.8)	50(19.5)	0.372
Sole usage	117(84.2)	207(80.5)	
Toilet type			
Other	0(0.0)	1(0.4)	0.462
Flush toilet	139(100.0)	256(99.6)	
Electricity			
No	3(2.1)	10(3.8)	0.366
Yes	137(97.9)	252(96.2)	

The study sample showed significant differences from the rest of the black participants in the Bone Health subgroup in maternal age, gravidity and parity ($p \leq 0.05$). The mothers in the study sample were younger, which implied that they had fewer pregnancies and fewer numbers of children than in the entire Bone Health black sample. However, there were no significant differences between the two samples with respect to the majority of the variables, namely sex, marital status, maternal education, gestational age, birth weight and socio-economic status at birth.

3.3 General description of study sample characteristics

Descriptive statistics stratified by sex were conducted for all the variables showing the mean values for infant nutrition and anthropometry and body composition age year 9 or 10 data and

socio-demographic variables at birth (Table 2). Prevalence of stunting, wasting and underweight in infancy are summarised in Graph 1.

3.3.1 Infant nutrition

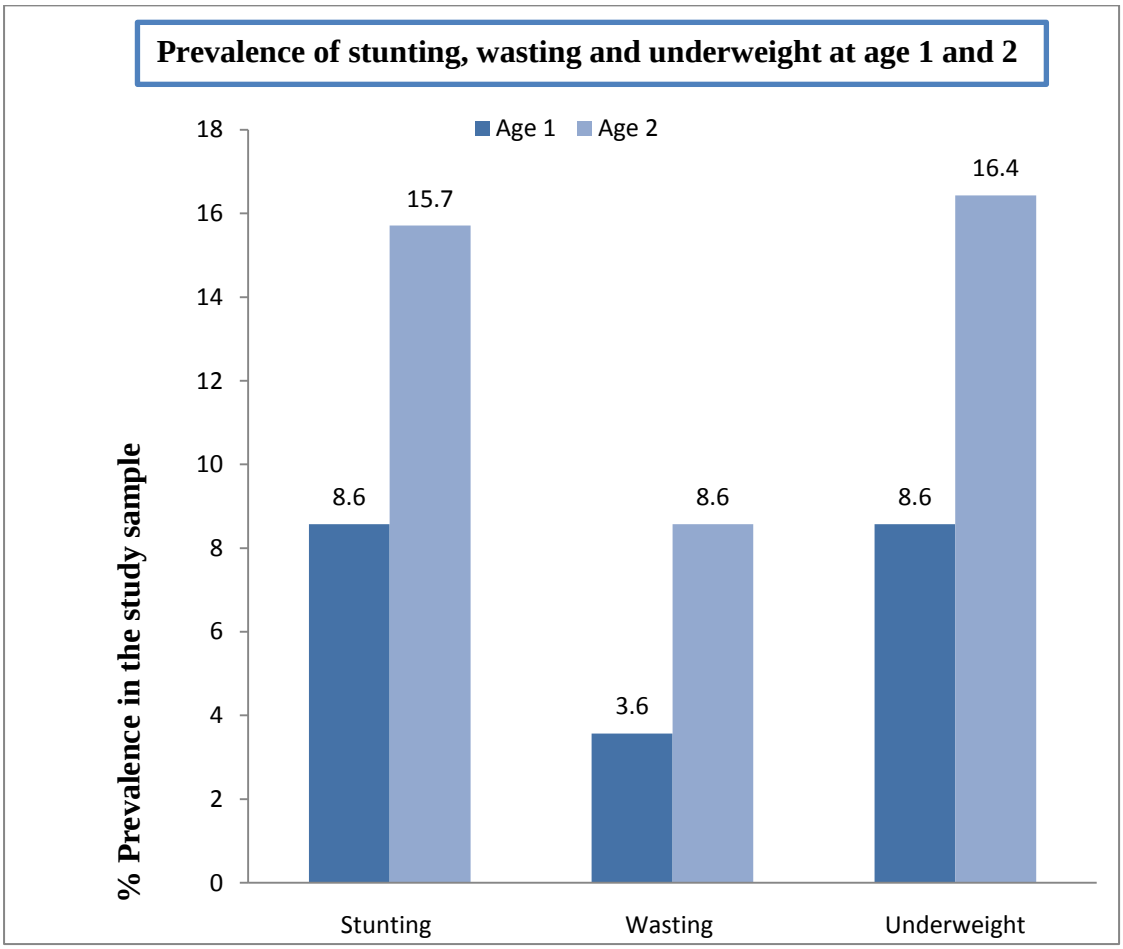
For infant nutrition variables, there was a significant sex difference in breastfeeding duration ($p=0.009$). Boys were breastfed, on average, for a shorter period (12.7 months) than girls (16.44 months). There were no marked differences between the boys and girls with regards to all the other infant nutrition variables, namely duration of bottle feeding, introduction of complementary feeding, dietary diversity and food variety scores. The mean duration for bottle feeding was on average 10.5 months while introduction of solids was done at 3 months in both boys and girls. In this study group, the DDS and FVS per day were on average one and two, respectively.

3.3.2 Infant anthropometry

There were significant gender differences in early life anthropometry with regard to birth weight, infant height (1 and 2 years of age) and wasting at 2 years. Boys were significantly heavier at birth (3213 g) than girls (3012 g), notably taller than girls at infancy and were on average, significantly lighter for their height (WHZ= -0.26) than girls (WHZ=+0.26) at 2 years ($p<0.05$). However, there were no pronounced sex differences in the rest of the early life growth variables.

Stunting, wasting and underweight at 1 year were 8.6% (n=12), 3.6% (n=5) and 8.6% (n=12), respectively. At 2 years of age, the prevalence of under-nutrition almost doubled resulting in 15.7% (n=22) stunting, 8.6% (n=12) wasting and 16.4% (n=23) underweight in this study sample (Graph 1).

Graph 1: Prevalence of stunting, wasting and underweight in 140 Black South African children born in Soweto in 1990 from the Bone Health sub-study.



3.3.3 Body composition at age 9/10 years

At 9/10 years of age, the mean fat mass for girls was significantly higher (9324 g) than in boys (6853 g, p=0.0012). This was a contrast to bone mineral content at certain sites where boys had markedly higher bone mass at the radius (1.1 g) than girls (1.0 g, p=0.0024) and femoral neck (3.1 g for boys) compared to the girls (2.7 g, p=0.0000). On the other hand, girls had marginally higher BMC at the lumbar spine (25.0 g) than boys (23.6 g, p=0.0534). For bone area, significant sex differences were noted at the radius and femur. Boys had higher bone area at the radius (2.3 cm^2) compared to girls (2.1 cm^2, p=0.000), while at the femur, boys had a bone area of 4.1 cm^2 compared to 3.9 cm^2 in girls (p=0.0052).

There were no significant sex discrepancies in age, height, weight, lean mass or bone mineral content and area for the whole body and lumbar spine at 9/10 years of age. Lean mass was higher in boys (21352 g) than girls (20728 g) though the difference was insignificant (p=0.3074).

3.3.4 Socio-economic status

There was a significant sex difference in socio-demographic characteristics in the study sample with respect to gravidity but not in the rest of maternal factors or in socioeconomic status. A higher proportion of the girls (55.4%, n=36) compared to boys (37.3%, n=28), were born to mothers as a result of first pregnancy. On the other hand, a lower number of girls (44.6%, n=29) as opposed to boys (62.7%, n=47) were born to mothers who had more than one pregnancy.

Table 2: Study sample characteristics of 140 children from the Bone health sub-study.

STUDY CHARACTERISTICS	**MALES**		**FEMALES**		**P-value**
Infant Nutrition[l]	**N**	**mean ± sd**	**N**	**mean ± sd**	
Breastfeeding/months	69	12.7±8.5	62	16.4±7.5	**0.0090***
Bottle feeding/months	65	10.5±5.7	47	10.5±5.2	0.9934
Complementary feeding/months	75	3.1±1.2	65	3.2±1.1	0.6963
Dietary diversity score	75	1.4±0.2	65	1.4±0.1	0.5495
Food variety score	75	1.88±0.7	65	2.00±0.7	0.8301
Early life anthropometry[l]					
Gestational age/wks	75	37.0±1.7	65	37.9±1.5	0.7925
Birth weight/g	75	3213±528	65	3012±450	**0.0178***
Age Yr 1	75	1.0±0.1	65	1.0±0.1	0.3043
Yr 1weight/kg	75	9.8±1.5	65	9.4±1.5	0.1191
Yr 1height/cm	75	74.7±3.1	65	72.8±3.3	**0.0009***
Yr 1HAZ score	75	-0.5±1.2	65	-0.6±1.1	0.7826
Yr 1WAZ score	75	-0.4±1.4	65	-0.1±1.3	0.3449
Yr 1WHZ score	75	0.1±1.4	65	0.5±1.4	0.0837
Age Yr 2	75	2.1±0.1	65	2.1±0.1	0.8636
Yr 2 Weight/kg	75	11.7±1.8	65	11.6±1.7	0.7971
Yr 2 Height/cm	75	84.0±3.6	65	82.6±3.8	**0.0288***
Yr 2 HAZ/score	75	-0.8±1.1	65	-0.9±1.2	0.4294
Yr 2 WAZ/score	75	-0.8±1.4	65	-0.4±1.3	0.0689
Yr 2 WHZ/score	75	-0.3±1.4	65	0.3±1.5	**0.0319***
Yr 9, 10 variables[l]					
Age (yrs)	75	10.4±0.4	65	10.4±0.4	0.1878
Weight(kg)	75	32.6±6.0	65	34.0±8.4	0.2727
Height(cm)	75	138±6	65	138±8	0.6790

Fat mass(g)	75	6853±3666	65	9324±5151	**0.0012***
Lean mass(g)	75	21352±3113	65	20728±4075	0.3074
Whole body BMC/g	75	723±24	65	811±645	0.2476
Whole body BA/cm²	75	1011±134	65	1029±179	0.4880
Radius BMC/g	74	1.1±0.1	65	1.0±0.1	**0.0024***
Radius BA/cm²	74	2.3±0.2	65	2.1±0.2	**0.0000***
Femoral neck BMC/g	74	3.1±0.4	65	2.7±0.5	**0.0000***
Femoral neck BA/cm²	74	4.1±0.3	65	3.9±0.4	**0.0052***
L1-L4 lumbar spine BMC/g	75	23.6±3.9	65	25.0±4.9	0.0539
L1-L4 lumbar spine BA/cm²	75	42.9±4.7	65	42.5±4.0	0.6688

Socio-demographic variables[2] (at birth)	**N(%)**	**N(%)**	**P value**
Maternal age			
13-18	15(20.0)	16(24.6)	0.358
19-29	48(64.0)	34(52.3)	
30+	12(16.0)	15(23.8)	
Maternal education			
≤st8	9(12.0)	8(12.3)	0.956
≥std9	66(88.0)	87(87.7)	
Marital status			
Single/separated/divorced/widowed	56(76.7)	53(81.5)	0.329
Married/living together	19(25.3)	12(18.5)	
Gravidity			
1	32(42.6)	38(58.5)	**0.032***
2+	43(57.3)	27(41.5)	
Parity			
1	28(37.3)	36(55.4)	0.062
2+	47(62.7)	29(44.6)	
House type			
House	68(90.7)	62(95.4)	0.280
Other	7(9.3)	3(4.6)	
House ownership			
Owned	48(64.0)	43(66.2)	0.790
Other	27(36.0)	22(33.9)	
SES-water type			
Indoor	31(41.9)	37(56.9)	0.077
Other	43(58.1)	28(43.1)	
SES-water usage			
Sole usage	61(82.4)	56(86.2)	0.549
Shared	13(17.6)	9(13.9)	
SES-Toilet usage			
Sole usage	62(83.8)	55(84.6)	0.893
Shared	12(16.2)	10(15.4)	
SES-Toilet type			
Flush inside	15(20.3)	21(32.3)	0.106
Other	59(79.8)	44(67.7)	
Refuse facility			
Garbage bin	73(98.6)	63(96.9)	0.485
Own refuse facility	1(1.4)	2(3.1)	
Electricity			
No	3(4.0)	0(0.0)	0.103
Yes	72(96.0)	65(100.0)	
Television			
No	15(20.0)	12(18.46)	0.818
Yes	60(80.0)	53(81.54)	
Car			
No	60(80.0)	46(70.8)	0.204
Yes	15(20.0)	19(29.2)	

Fridge			
No	22(29.3)	12(18.5)	0.135
Yes	53(70.7)	53(81.5)	
Washing machine			
No	68(90.7)	56(87.5)	0.549
Yes	7(9.3)	8(12.5)	
Phone			
No	32(42.7)	22(33.9)	0.285
Yes	43(57.3)	43(66.2)	

*Significant at P≤0.05
[1] t-test
[2]Pearson's chi square test

3.4 Bivariate analysis

The first stage of bivariate analysis included simple regressions to check associations between early life exposure and subsequent outcome variables namely: fat mass lean mass bone mineral content of the whole body, radius, femur and lumbar spine. The unadjusted regression results are tabulated in Appendix 5. Multiple regressions were thereafter conducted to check for associations between the exposures and outcomes allowing for several confounders. The results are in Table 3 and Table 4 for associations between early life variables and anthropometry, and then pre-pubertal body composition, respectively.

3.5 Association between early life variables and anthropometry (age 1, 2 and 9/10)

Table 3 shows the multivariate models results of the associations of birth weight z-scores and infant nutrition with growth at 1, 2 and 9/10 years of age. Infant nutrition variables included breastfeeding, bottle feeding, complementary feeding and dietary and food diversity scores. The table presents the linear and logistic regression outputs from testing for relationships between the selected variables.

3.5.1 Association between birth weight and anthropometry at age 1, 2 and 9/10

Birth weight was significantly associated with height and weight at 1, 2 and 9/10 years of age after adjusting for confounders (Table 3). In the multivariate model, there was a significant association between birth weight z-score and stunting at 1 year and not at 2 years; for every unit increase in birth weight z-score, the likelihood of being stunted at 1 year decreased by

approximately 60% (OR=0.40, CI=0.19-0.83, p=0.013) independent of the above-mentioned confounders. There also was a statistically significant relationship between birth weight and being underweight at 1 year and not 2 years, independent of confounders. The odds ratio of birth weight z-score was 0.31 (CI=0.15-0.65, p=0.02), indicating that the prevalence of underweight decreased by 69% per unit increase in birth weight z-score in this study. There was no relationship between birth weight z-score and wasting in infancy even after allowing for confounders.

3.5.2 Association between infant nutrition and anthropometry at age 1, 2 and 9/10

There was a significant association between time of onset of complementary feeding and height at 1 year even after accounting for gender, household environment and maternal education. Height z-score at 1 year increased with delayed introduction of solids since a unit increase in months at which complementary feeding was introduced resulted in 0.21 increase in height z-score (β=0,21 CI=0.08-0.35, p=0.003). There were no significant associations between all the other infant nutrition variables and anthropometry at 1, 2 and 9/10 years of age.

3.5.3 Association of anthropometry at age 1, 2 and 9/10

Height and weight z-scores at 1 year were strongly positively associated with both height and weight z-scores at age 2 and age 9/10, respectively ($p \leq 0.001$). An increase in weight z-score at age 1 significantly resulted in the children having an increase in weight z-score at age 2 and 9/10 years, while those were taller at age 1 year also tended to be notably taller at 2 and 9/10 years of age.

Stunting at age 1 year was significantly associated with height at age 2 and 9/10 years. Those who were stunted at age 1 year were shorter at age 2 and 9/10 years than those who were not stunted, independent of confounders. There was a marginally significant association between

stunting at age 1 year and weight at 2 years, but not at age 9/10 years after adjusting for gender, birth weight, household environment and maternal education (Table 3). The infants who were stunted at age 1 year had also lower weight at age 2 years than those who were non-stunted (β=-0.63, CI=-1.24-0.01, p=0.046). There was a 12-fold likelihood of stunting at age 2 years if the infant was stunted at age 1 year (OR=12.63, CI=2.56-62.25, p=0.002) than those who were not stunted. There were no relationships between stunting at age 1 year and wasting and underweight at age 2 years.

Wasting at age 1 year was significantly related to weight and height at age 2 years, but not with wasting at 2 years or weight and height at age 9/10 years. Infants who were wasted at age 1 years had lower weight and height at age 2 as compared to their non-wasted counterparts (Table 3). There was a high risk of being underweight (OR=19.7, CI=1.39-279.3, p=0.027) or stunted (OR=85, CI=3.5-2067.9, p=0.006) at age 2 year for the infants who were wasted in the first year of life.

Being underweight at age 1 was strongly associated with weight, height stunting and underweight at age 2, and height at age 9/10 after adjusting for confounders (Table 3). The more an infant was underweight at age 1, the lower their weight and height at age 2. Those who were underweight at age 1 were 27 times more likely to be stunted (OR=27.14, CI=3.83-192.36, p=0.007) and 8.6 times more likely to be underweight (OR=8.60, CI=1.83-40.54, p=0.007) at age 2. There was no association between being underweight at age 1 and wasting at age 2 years or also pre-pubertal height after adjusting for sex, birth weight, maternal education and household environment.

3.5.4 Association between anthropometry at ages 2 years and 9/10 years

Weight at age 2 years was significantly associated with weight and height at age 9/10. A strong association also was found between height at age 2 and anthropometry at age 9/10

($p \leq 0.001$). Stunting at age 2 years had a significant relationship with height ($\beta = -0.05$, CI= -0.08-0.03, p=0.000) but not with weight at age 9/10 years. There also was a significant association between underweight at age 2 and pre-pubertal weight and height. Those who were underweight at age 2 years were lighter and shorter at age 9/10 years than those who were not underweight. Non-significant associations were noted between wasting at age 2 years and anthropometry at age 9/10 years.

Table 3: Association between early life variables in black South African children from the Bone health sub-study (N=140) (Multivariate model)

Variable	Weight Yr1[1] β (95%CI) p-value	Height Yr1[1] β (95%CI) p-value	Stunting Yr1[2] OR (95%CI) p-value	Wasting Yr1[2] OR (95%CI) p-value	Underweight Yr1[2] OR (95%CI) p-value		
At birth							
Birth weight z-score	0.44(0.28-0.59) **0.000***	0.31(0.15-0.47) **0.000***	0.40(0.19-0.83) **0.018***	0.51(0.18-1.50) 0.224	0.31(0.15-0.65) **0.020***		
Infant feeding							
Breastfeeding duration	-0.02(-0.04-0.01) 0.159	-0.02(-0.04-0.01) 0.144	1.00(0.91-1.10) 0.969	1.24(0.86-1.77) 0.249	1.04(0.94-1.14) 0.477		
Bottle-feeding duration	-0.003(-0.02-0.02) 0.758	-0.008(-0.03-0.01) 0.432	1.02(0.90-1.17) 0.741	0.95(0.66-1.38) 0.795	0.97(0.83-1.14) 0.709		
Introduction of solids	0.02(-0.11-0.16) 0.731	0.21(0.08-0.35) **0.003***	0.57(0.31-1.05) 0.071	1.58(0.33-1.48) 0.567	0.63(0.31-1.26) 0.192		
Dietary diversity score	0.02(-0.14-0.19) 0.769	0.02(-0.15-0.19) 0.819	1.10(0.55-2.23) 0.782	0.68(0.13-3.48) 0.643	0.88(0.45-1.74) 0.717		
Food variety score	0.02(-0.22-0.26) 0.881	-0.03(-0.26-0.21) 0.826	0.90(0.31-2.66) 0.852	0.40(0.03-5.44) 0.493	0.68(0.22-2.13) 0.512		
	Weight Yr 2[1] β (95%CI) p-value	**Height Yr2[1]** β (95%CI) p-value	**Stunting Yr2[2]** OR (95%CI) p-value	**Wasting Yr2[2]** OR (95%CI) p-value	**Underweight Yr2 [2]** OR (95%CI) p-value	**Weight Yr 9,10 [1]** β (95%CI) p-value	**Height Yr 9,10 [1]** β (95%CI) p-value
At birth							
Birth weight z-score	0.33(0.16-0.50) **0.000***	0.33(0.16-0.49) **0.000***	0.65(0.39-1.08) 0.095	0.64(0.33-1.23) 0.183	0.64(0.39-1.07) 0.088	0.05(0.02-0.08) **0.002***	0.01(0.00-0.002) **0.048***
Infant feeding							
Breastfeeding duration	0.005(-0.02-0.03) 0.697	0.002(-0.02-0.02) 0.838	0.99(0.92-1.07) 0.804	1.09(1.00-1.20) 0.085	1.00(0.93-1.07) 0.923	0.002(-0.002-0.006) 0.342	-0.003(-0.001-0.001) 0.568
Bottle-feeding duration	0.03(-0.01-0.06) 0.126	0.03(-0.01-0.06) 0.099	0.95(0.84-1.07) 0.394	1.07(0.94-1.22) 0.317	0.99(0.88-1.13) 0.927	-0.005(-0.01-0.001) 0.117	0.00001(-0.002-0.003) 0.985
Introduction of solids	-0.06(-0.21-0.09) 0.405	0.09(-0.06-0.24) 0.227	1.03(0.65-1.62) 0.912	1.53(0.88-2.66) 0.130	1.37(0.82-2.28) 0.225	0.004(-0.02-0.03) 0.766	0.002(-0.005-0.010) 0.538
Dietary diversity score	0.07(-0.11-0.25) 0.449	-0.02(-0.20-1.59) 0.823	0.83(0.48-1.44) 0.506	0.80(0.44-1.44) 0.456	1.14(0.66-1.97) 0.628	-0.002(-0.04-0.03) 0.913	-0.003(-0.011-0.010) 0.715
Food variety score	0.18(-0.07-0.44) 0.161	-0.01(-0.27-0.24) 0.937	1.08(0.47-2.47) 0.858	0.74(0.24-2.31) 0.608	1.05(0.44-2.50) 0.912	-0.03(-0.08-0.02) 0.271	-0.004(-0.02-0.01) 0.530
Anthropometry at Infancy							
Weight Yr 1	0.70(0.57-0.83) **0.000***	0.48(0.32-0.64) **0.000***	0.11(0.04-0.34) **0.000***	0.53(0.21-1.34) 0.177	0.11(0.04-0.34) **0.000***	0.09(0.06-0.12) **0.000***	0.02(0.01-0.03) **0.000***
Height Yr1	0.49(0.35-0.65) **0.000***	0.61(0.46-0.76) **0.000***	0.12(0.05-0.32) **0.000***	1.02(0.49-2.12) 0.966	0.46(0.25-0.87) **0.017***	0.06(0.03-0.09) **0.001***	0.03(0.02-0.04) **0.000***
Stunting yr 1	1	1	1	1	1	1	1

	-0.63(-1.24- -0.01) **0.046***	-0.86(-1.45- -0.29) **0.004***	12.63(2.56-62.25)**0.002***	0.65(0.05-8.03) 0.739	2.52(0.44-14.30) 0.798	-0.11(-0.23-0.01) 0.064	-0.05(-0.08- -0.02) **0.004***
Wasting Yr1	1	1	1	1	1	1	1
	-0.99(-1.91- -0.07) **0.035***	-0.95(-1.86- -0.03) **0.042***	19.7(1.39-279.3**) 0.027***	16.8(0.88-19.28)0.061	85.2 (3.5-2067.9) **0.006***	-0.04(-0.22-0.14) 0.663	-0.03(-0.08-0.02) 0.280
Underweight Yr1	1	1	1	1	1	1	1
	-0.90(-1.50- -0.30) **0.004***	-1.08(-1.67- -0.50) **0.000***	27.1(3.83-192.36)**0.001***	2.72(0.35-21.12) 0.337	8.60(1.83-40.54) **0.007***	-0.07(-0.19-0.05) 0.245	-0.04(-0.08- -0.01) **0.007***
Height Yr 2	-	-	-	-	-	0.10(0.07-0.13) **0.000***	0.02(0.01-0.03) **0.000***
Weight Yr 2	-	-	-	-	-	0.06(0.02-0.09) **0.001***	0.03(0.02-0.03) **0.000***
Stunting Yr 2	-	-	-	-	-	1	1
						-0.08(-0.17-0.01) 0.074	-0.05(-0.08- -0.03) **0.000***
Wasting Yr 2	-	-	-	-	-	1	1
						-0.07(-0.19-0.04) 0.215	-0.01(-0.05-0.02) 0.397
Underweight Yr 2	-	-	-	-	-	1	1
						-0.12(-0.20- -0.01) **0.023***	-0.03(-0.05- -0.004) **0.025***

[1]Linear regression: β (95%CI) p-value

[2]Logistic regression: OR (95%CI) p-value

[3]Weight and height at age 1 and 2 years given as z-scores

Adjusted for gender, maternal education, household environment and gestational age

Adjusted for gender, maternal education, household environment and birth weight

*Significant at P≤0.05

~marginally significant

3.6 Association between early life variables and age 9/10 body composition

Table 4 lists the associations between early life variables (birth weight, infant nutrition and anthropometry) and composition at age 9/10 years (fat, lean and bone mass at specific sites).

3.6.1 Birth weight and later body composition

Birth weight was a strong predictor of lean mass and bone mineral content at the radius, femur and lumbar spine (Appendix 5), but the relationship remained for the radius and lumbar spine only after adjusting for current height and weight, age and gender (Table 4). A unit increase in birth weight z-score resulted in a 2% increase in lean mass (β=0.02, CI=0.005-0.030, p=0.007), independent of age, body size and gender. For radius and lumbar spine, a unit increase in birth weight z-score resulted in a significant 2% (β=0.02, CI=-0.01-0.03, p=0.039) and 3% (β=0.03, CI=0.005-0.05, p=0.018) increase in bone mineral content respectively in the multivariate model. The multiple regressions for birth weight were statistically insignificant for fat mass and bone mineral content at the femur and the whole body.

3.6.2 Infant nutrition and later body composition

Early feeding variables were not significantly associated with later body composition after adjusting for age and gender. There was no association between either bottle feeding or breastfeeding and body composition. Furthermore, timing of weaning and the dietary diversity and food variety scores did not statistically influence body composition independent of socio-economic status, maternal education and body size at age 9/10 and birth weight.

3.6.2 Infant anthropometry and later body composition

Height (with exception of height at age 2 which was not a significant predictor of fat mass) and weight during 1 and 2 years were significantly associated with fat, lean and bone mass at all sites (Appendix 5). After adjusting for age, gender, birth weight and current body size, the

only relationships that persisted were those of height at age 1 with fat and lean mass plus weight at age 2 years and bone mineral content at the radius. There was a positive relationship between height at age 1 year and fat mass at age 9/10 years (Table 4) with a unit increase in height z-score predicting a 7% increase in fat mass (β=0.07, CI=0.04-0.11, p=0.000). In contrast, height at age 1 had a notable inverse association with lean mass; the taller an infant was at age 1, the leaner they were at age 9/10 years (β= -0.02, CI=-0.03 to -0.03, p=0.017). Height at age 2 years did not significantly predict fat, lean and bone mineral content in the multivariate model (Table 4). There was a significant inverse association between weight at age 2 and bone mineral content at the radius only, with a unit increase in weight z-score predicting in a 3% decline in BMC at the radius (β=-0.03, CI= -0.05- -0.003, p=0.026). However, statistically, weight at age 1 had no association with fat, lean or bone mass at age 9/10 years after adjusting for birth weight, gender, current age and body size.

From the univariate table (Appendix 5), those infants who were stunted at 1 year had significantly lower fat mass, lean mass and bone mass at age 9/10 years except for the femur where those who were stunted had significantly higher BMC at the femur. This association remained significant at age 2 years. Stunting at infancy was significantly associated with fat mass only after adjusting for confounders (Table 4). Fat mass was 18% (β= -0.18, CI= -0.30- - 0.06, p=0.003) and 12% (β= -0.12, CI= -0.22- -0.03, p=0.011) lower in those who were stunted at age 1 and 2 respectively, compared to those who were not stunted. Lean and bone mass were not significantly associated with stunting at infancy in the multivariate model.

Being underweight at age 1 year was significantly associated with lower lean mass and whole body, radius and lumbar spine bone mineral content. However, after adjusting for confounders, the associations became insignificant except at the whole body where there was a marginal association between being underweight at age 1 year and bone mineral content at the whole body (p=0.054). Those who were underweight had lower whole body bone mineral

content as compared to the non-underweight in infancy. At age 2 years, being underweight was only a predictor of lower fat mass, otherwise, weight-for-age at age 1 and 2 years was not a significant predictor of fat and lean mass or bone mineral content at specific sites. There were statistically no relationships between wasting at age 1 and 2 years and fat, lean or bone mass.

Table 4: Association between early life variables and age 9/10 years body composition in black South African children from the Bone health sub-study (N=140) (multivariate model)

Variable	Fat mass/g		Lean mass/g		Whole body/BMC		Radius/BMC		Femur/BMC		Lumbar spine/BMC	
At birth												
Birth weight z-score	-0.02(-0.05-0.02)	0.378	0.02(0.005-0.03)	**0.007***	-0.003(-0.04-0.03)	0.883	0.02(0.00-0.04)	**0.039***	0.01(-0.01-0.03)	0.445	0.03(0.01-0.05)	**0.018***
Infant nutrition												
Breastfeeding duration	0.004(-0.005-0.014)	0.396	-0.0004(-0.004-0.003)	0.806	0.002(-0.004-0.003)	0.604	-0.001(-0.004-0.002)	0.604	-0.001(-0.004-0.002)	0.648	0.001(-0.002-0.005)	0.483
Bottle-feeding duration	-0.01(-0.03-0.003)	0.107	-0.001(-0.006-0.004)	0.572	-0.003(-0.012-0.007)	0.564	0.00003(-0.005-0.005)	0.989	-0.002(-0.01-0.003)	0.401	-0.002(-0.01-0.004)	0.555
Introduction of solids	0.02(-0.05-0.08)	0.588	-0.001(-0.02-0.02)	0.951	0.03(-0.01-0.07)	0.103	0.0001(-0.02-0.02)	0.991	0.005(-0.01-0.02)	0.623	-0.01(-0.03-0.01)	0.460
Dietary diversity score	0.006(-0.07-0.09)	0.880	0.01(-0.02-0.04)	0.410	0.03(-0.02-0.07)	0.288	0.003(-0.03-0.02)	0.788	-0.006(-0.03-0.02)	0.599	-0.03(-0.01-0.005)	0.199
Food variety score	-0.04(-0.15-0.07)	0.457	-0.005(-0.04-0.03)	0.791	0.01(-0.05-0.08)	0.676	-0.02(-0.06-0.01)	0.174	-0.03(-0.06-0.002)	0.061	-0.01(-0.06-0.03)	0.522
Anthropometry at infancy												
Age Yr1:												
Weight	0.01(-0.03-0.05)	0.594	-0.002(-0.02-0.01)	0.761	0.01(-0.04-0.07)	0.687	-0.01(-0.03-0.02)	0.661	0.01(-0.02-0.03)	0.310	0.01(-0.02-0.04)	0.459
Height	0.07(0.04-0.11)	**0.000***	-0.02(-0.03- -0.003)	**0.017***	-0.003(-0.05-0.04)	0.900	-0.02(-0.04-0.005)	0.116	-0.002(-0.02-0.02)	0.880	0.004(-0.02-0.03)	0.754
Stunting												
Normal	1		1		1		1		1		1	
Stunted	-0.18(-0.30- -0.06)	**0.003***	0.03(-0.01-0.08)	0.122	-0.07(-0.21-0.07)	0.326	0.01(-0.06-0.08)	0.842	-0.02(-0.09-0.05)	0.566	-0.03(-0.12-0.04)	0.407
Wasting												
Normal	1		1		1		1		1		1	
Wasted	0.13(-0.05-0.30)	0.147	-0.04(-0.10-0.02)	0.215	-0.12(-0.32-0.07)	0.215	-0.09(-0.20-0.01)	0.068	-0.06(-0.15-0.04)	0.252	-0.08(-0.20-0.04)	0.170
Underweight												

Normal	1		1		1		1		1		1	
Underweight	-0.04(-0.16-0.09)	0.562	-0.01(-0.06-0.04)	0.670	-0.14(-0.28-0.002)	0.054	-0.06(-0.13-0.12)	0.126	-0.04(-0.10-0.03)	0.300	-0.07(-0.16-0.01)	0.078
Age Yr2												
Weight	0.02(-0.02-0.06)	0.265	0.004(-0.01-0.02)	0.579	-0.01(-0.06-0.04)	0.663	-0.03(-0.05- -0.003)	**0.026***	-0.001(-0.02-0.02)	0.940	-0.01(-0.04-0.01)	0.289
Height	0.03(-0.01-0.07)	0.185	0.0002(-0.01-0.01)	0.972	-0.01(-0.05-0.03)	0.659	-0.01(-0.03-0.01)	0.321	-0.002(-0.02-0.02)	0.857	0.01(-0.01-0.04)	0.332
Stunting												
Normal	1		1		1		1		1		1	
Stunted	-0.12(-0.22- -0.03)	**0.011***	0.01(-0.03-0.04)	0.608	0.04(-0.07-0.15)	0.481	0.001(-0.54-0.06)	0.962	-0.02(-0.08-0.03)	0.431	-0.05(-0.12-0.01)	0.077
Wasting												
Normal	1		1		1		1		1		1	
Wasted	-0.02(-0.14-0.09)	0.710	-0.01(-0.05-0.03)	0.570	-0.05(-0.18-0.05)	0.480	-0.01(-0.08-0.06)	0.734	-0.03(0.10-0.03)	0.313	-0.001(-0.08-0.08)	0.977
Underweight												
Normal	1		1		1		1		1		1	
Underweight	-0.01(-0.20-0.01)	**0.023***	-0.002(-0.04-0.03)	0.928	-0.005(-0.11-0.10)	0.933	0.02(-0.03-0.08)	0.464	-0.02(-0.07-0.03)	0.436	0.03(-0.03-0.09)	0.366

[1]Weight and height at age 1 and 2 years in z-scores

Adjusted for current age, body size and gender

Adjusted for birth weight, current age, body size and gender

*significant at $p \leq 0.05$

~marginally significant

3.7 Summary

The results highlighted some significant sex differences in some variables namely: breast feeding, birth weight, infant height at ages one and two years, weight-for-height z-score at two years of age, fat mass, bone area and mineral content at the radius and femur. From the multivariate analysis, there were some significant associations between some early life and growth and body composition variables at age 9/10 years. The study sample represented the entire Bone Health sub study except for a few socio-demographic variables.

CHAPTER FOUR: DISCUSSION

4.1 Introduction.

This chapter discusses the main findings from this study, sample selectivity and general description of the variables with regards to associations of birth weight, infant nutrition and growth with subsequent pre-pubertal body composition in black South African children from the Birth-to-Twenty longitudinal study cohort. It also encompasses how the findings fit in with previous studies in this field. An outline of limitations and strengths of this study are also included in this discussion.

4.2. Main findings.

The main objective of this study was to describe the associations between early life variables (birth weight, infant anthropometry and nutrition) and body composition at age 9/10 years of age. From the results, we found out that birth weight, a proxy for prenatal nutrition, and infant anthropometry (a nutrition assessment tool) were associated with subsequent height, weight, lean and bone mass at age 9/10 years. However, there was no significant association between infant nutrition and anthropometry and body composition age 9/10 years.

As hypothesised in our study, all infant nutrition variables were not significantly associated with subsequent body composition at age 9/10 years. However, from the results, there was evidence of possible programming of body composition at age 9/10 years by anthropometry (birth weight and infant anthropometry).

4.3 General description of study variables.

The general description of all the variables from those at birth, infancy, pre-pubertal stage and socio-economic status were done by sex to explore trends in the study sample.

4.3.1 Household socio-economic status at delivery.

From the current study, there were no significant sex discrepancies with respect to all demographic and socio-economic variables except that more girls were born to mothers as first pregnancy compared to boys, probably due to chance. However, although a majority of children were born to parents who had their own houses, a greater proportion of these households had no access to indoor water and in-house flush toilet (Table 2). This is often an indicator of poor sanitation and low socio-economic status and could mean that food contamination was inevitable leading to infants' exposure to infections (79) and probably resulting in growth faltering in early life (80).

4.3.2 Anthropometry at infancy.

In our study, consistent with a previous study using Birth-to-Twenty data, we found out that boys were significantly heavier at birth and taller as infants, but also more wasted than girls at age 2 (81). These early life gender differences in physical growth can be explained by differing levels of sex-dependent growth regulating genes (82). Boys have higher levels of testosterone during the gestation period and early postnatal life which is responsible for faster physical and linear growth in males than in females (83). The boys also were significantly lighter for their height (WHZ) at age 2 compared to girls. This could have been due to their differences in height mentioned above.

4.3.3 Infant nutrition.

From our results, on average, girls were significantly breast-fed longer than boys. This finding was consistent with previous studies (84;85). We speculated that this was either due to gender preference in nursing or, as suggested by other authors (86;87), that boys have a higher energy intake than girls and mothers feel that breast milk was not enough for the boy infants.

Data from the unquantified FFQ showed that on average that the infants were on a low diversity weaning diet, with a mean DDS of 1 and FVS of 2 per day. In the Arimond study, researchers found that the mean dietary diversity score for countries like Mali, Malawi and Ethiopia were on average 2 (88). Another study done in South Africa conducted across all ethnic groups found that the mean DDS and FVS for 1-3 year old children was 3.51 and 5.37 respectively, concluding that dietary diversity is limited in many early childhood diets in South Africa (89).

4.3.4 Body composition at age 9/10 years.

In this study, as highlighted by previous studies, girls had significantly greater fat than boys at age 9/10 years (90;91). On the other hand, boys had greater lean mass than girls, but the difference was insignificant. These sex-based differences in lean and fat mass have been attributed to differences in energy allocations with females acquiring higher levels of body fat as an investment for reproductive fitness while boys tend to have greater lean mass for aiding resource acquisition (86). Some authors suggested that the sex differences in fat and fat-free mass at this age are due to differing gonadotropin and steroid levels even before puberty (92).

From the results, although there were no sex differences in bone mineral content (BMC) for the whole body, boys had greater BMC and bone area at the femoral neck and radius while girls had higher BMC at the lumbar spine. We speculated that since bone mineral content at the femur and radius are influenced mainly by weight-bearing physical activity (93), boys should have been more physically active than girls. These findings were consistent with a Tasmanian study (94).

4.4 Association between early life factors and body composition at age 9/10 years.

4.4.1 Infant nutrition, anthropometry and body composition at age 9/10 years.

Infant nutrition variables used in this study were breastfeeding and bottle feeding duration, introduction of solids, dietary diversity and food variety score. Delayed introduction of solids significantly predicted greater height at age 1 year. Otherwise, there were no other significant short and long term associations between all the other infant feeding variables and subsequent infant growth and pre-pubertal body composition. Many studies have failed to find consistent results on association of infant feeding with growth and later fat mass (95), lean mass (96) and bone mass (97).

4.4.2 Birth weight and anthropometry and body composition at age 9/10 years.

In this study, we found that lower birth weight was associated with subsequent lower weight and height at infancy and pre-puberty. Infants with lower birth weight were significantly more likely to be stunted and underweight at age 1, indicating that growth faltering persisted into the first year of postnatal life in this population. These findings suggest that under-nutrition in early life may not only expose individuals to chronic disease risk in later life (98), but also can alters their growth trajectory, with low birth weight infants growing slower and subsequently attaining a smaller and lighter pre-pubertal size (61). These findings were consistent with previous studies supporting the notion that growth trajectory tracks from foetal life (99;100).

From our study, we postulated that lean mass and site specific bone mass at the femur and lumbar spine, not fat mass, can be programmed in early life by birth weight since an increase in birth weight z-score resulted in a significant increase in lean mass at age 9/10 years even after adjusting for confounders. This finding is consistent with the 'hypothesis of "foetal origins developmental plasticity" by Kuzawa et al. (101) which stated that prenatal under-

nutrition may have long-term health effects by permanently altering structure and functions of organs, endocrine and metabolic system. Our results support a number of similar findings in other populations (102-105), suggesting that the trajectory of bone and muscle growth is set in prenatal life. The relationship between birth weight and lean mass at age 9/10 years if further investigated could provide be a link between low birth weight and chronic disease risk (106).

4.4.3 Infant anthropometry and body composition at age 9/10 years.

The association between growth at age 1 years and subsequent growth at ages 2 and 9/10 years shows that growth faltering in early life can have persistent effect on the growth trajectory of an individual. This also was evidenced by the findings that those who were lighter and shorter at one year were more likely to be stunted and underweight at age 2.

From the bivariate results (Appendix 5), weight, height, stunting and underweight during infancy were significantly associated with lean and site-specific bone mass at the radius, femur and lumbar spine, showing that growth faltering in infancy can leave an irreversible mark on bone and muscle mass hence influences fracture risk (61;107). Infant growth primarily determines the skeletal envelope size, meaning that skeletal growth trajectory is established in early life (63;108). From these findings, we suggest that catch-up growth of infants from a malnourished background may be beneficial for bone mass accrual as persistent stunting may have adverse long-term effects on bone health and fracture risk.

In this study, we found that those who were stunted in infancy were significantly leaner and had lower fat mass at the pre-pubertal stage compared to their non-stunted counterparts. The findings were consistent with those from a low income study cohort in Kingston, Jamaica (65). In the Kingston study, researchers found that children aged between 7 and 11 years who were stunted in infancy between 9 and 24 months of age, were leaner and had lower fat than

those who were non-stunted. These findings were not consistent with other studies which either found significant positive associations (60;109) or no relationships (81) between stunting in infancy and fat mass in late childhood.

From our results, we did to find any evidence to support the notion that stunting in infancy is a risk factor for obesity in late childhood. This could have been caused by the fact that the children in our study sample, like the Jamaican sample (65), were from a low income area and their household food security was still low or that they had not reached the stage of obesity rebound like the Brazilian children who were aged 11-15 years in another study finding positive associations between stunting in infancy and fat mass in late childhood (60).

4.5 Study limitations and strengths

From the results, we conclude that despite a number of expected findings, there is need to acknowledge the limitations and strengths of the study.

4.5.1 Study limitations.

This study had some potential limitations which are outlined below:

- ***Selection bias***: In comparison to the Bone Health sub-study, this study group comprised of younger mothers, who had fewer number of pregnancies and children than those from the rest of the black Bone Health sub-group. Some studies hypothesised that younger mothers are unlikely to exclusively breastfeed longer than their older counterparts (110). However, in our study, there was no evidence to support this hypothesis.
- ***Infant nutrition and anthropometry***: Firstly, the infant feeding variables such as duration of breastfeeding, bottle feeding and timing of introduction of solids were not categorised according to the infant feeding recommendations (111). Therefore, the effect of infant feeding in this study would not find any basis for influencing infant

feeding policy. The breastfeeding variable, though it was considered exclusive, from the summary statistics it was revealed that there could some false reporting in the duration of breastfeeding since the data was collected retrospectively.

Dietary intake was assessed using an unquantified FFQ which was based on specific foods and their groups and not on the actual amount of food consumed by the infant, making it difficult for us to establish whether the weaning diet had any effect on either immediate growth or subsequent growth and body composition at age 9/10 years. Furthermore, the mean DDS of 1 and FVS of 2 could imply that there could have been some under-reporting since the FFQ data was collected retrospectively and this method has been recently reported to have measurement error and recall bias (112;113).

Data used for anthropometry could have been correlated hence interfered with the analysis and interpretation of results.

4.5.2 Study strengths.

Despite the above-mentioned limitations, this study had a number of strengths including:

- ***Use of longitudinal data***: The most important strength of this study was the use of longitudinal data from Birth-to-Twenty study cohort. It allowed us to check associations of early life growth, nutrition and socio-demographic variables with subsequent growth patterns and body composition at pre-puberty in a developing country undergoing a dramatic socio-economic transition.
- ***Assessment of growth as nutrition status indicator***: In our study, we decided to assess the associations between early life growth and subsequent body composition. Infant growth was used as a nutrition status indicator by use of z-scores which were

categorised according to the recommended WHO cut-offs for moderate malnutrition (75).

4.6 Implications of the study for public health.

Of importance, is the implication of our result for low income countries undergoing a socio-economic and nutrition transition such as South Africa. Our data showed that growth faltering in infancy resulted in lower fat, lean mass and bone mass at pre-puberty, showing that there could be a higher risk of cardio-vascular diseases and fracture risk among those who were stunted and underweight in early postnatal life. However, this speculation needs further investigation. Delayed patterns of growth at late childhood followed by catch-up growth during puberty or nutritional affluence can increase obesity risk in later life.

Based on the findings from our study, we suggest that one way of promoting lean and bone mass accretion at age 9/10 years is by optimising prenatal and infant growth. From a public health perspective, there is need for evidence-based interventions and policies that are directed to, firstly, prenatal care to reduce prevalence of low birth weights and secondly, programs to monitor and support the promotion of optimal infant growth.

Maternal nutrition should also be a public health priority with the launching of intervention programmes that target women of reproductive age and nutrition counselling prior to conception and during pregnancy for optimal birth outcomes like birth weight. Development of early life nutrition intervention strategies that are evidence-based to prevent growth faltering at infancy also is a priority. However, because of inconsistency in our findings with other studies around the programming of body composition by early nutrition, it might be premature to make policy recommendations at this stage regarding infant feeding.

4.7 Future research studies.

This study, if further investigated can build onto the body of evidence supporting the developmental origins of adult health and disease hypothesis (114). The majority of these studies were conducted in non-African countries because of lack of resources to fund longitudinal studies. In Africa, most of the studies done were cross-sectional as compared to this study which used longitudinal data from the Bone health sub-group of the Birth-to-Twenty study cohort. To extend the body of evidence from this study, there is need to explore the associations between early life environment and the disease risk in adulthood, and as the cohort is now 20 years of age, it will be possible to examine this relationship.

4.8 Conclusion.

From this study, we found out that birth weight, a proxy for prenatal nutrition, and infant anthropometry (a nutrition assessment tool) were associated with subsequent height, weight, lean and bone mass at age 9/10 years indicating that growth trajectory, lean mass and the skeleton may be set from birth. Growth faltering (stunting and underweight) during infancy as was associated with lower fat, lean mass and bone mass at late childhood showing that exposure to under-nutrition in early life can leave a persistent effect on late childhood stature, fat, bone mass and muscle mass. These associations are confounded by gender, age and birth weight.

Interesting to note was that lean mass increased with birth weight and those who were stunted had lower lean mass than their non-stunted counterparts. This finding may imply that organ development and functionality might be influenced by adverse conditions acting in early life leaving an irreversible effect on organ functionality and metabolic capacity in late childhood, which is a risk factor for metabolic diseases. This hypothesis will be tested in my future PhD studies where the associations between early life environment and later cardiovascular and metabolic disease risk will be explored.

REFERENCE LIST

(1) Barker DJ. Developmental origins of adult health and disease. J Epidemiol Community Health 2004 Feb;58(2):114-5.

(2) Victora CG. Nutrition in early life: a global priority. Lancet 2009 Oct 3;374(9696):1123-5.

(3) Chomtho S, Wells JC, Williams JE, Davies PS, Lucas A, Fewtrell MS. Infant growth and later body composition: evidence from the 4-component model. Am J Clin Nutr 2008 Jun;87(6):1776-84.

(4) Kuzawa CW. Foetal origins of developmental plasticity: are foetal cues reliable predictors of future nutritional environments? Am J Hum Biol 2005 Jan;17(1):5-21.

(5) Lucas A. The developmental origins of adult health and well-being. Adv Exp Med Biol 2005;569:13-5.

(6) Wells JC, Fewtrell MS. Is body composition important for paediatricians? Arch Dis Child 2008 Feb;93(2):168-72.

(7) McDade TW, Beck MA, Kuzawa C, Adair LS. Prenatal undernutrition, postnatal environments, and antibody response to vaccination in adolescence. Am J Clin Nutr 2001 Oct;74(4):543-8.

(8) Neu J, Hauser N, Douglas-escobar M. Postnatal nutrition and adult health programming. Semin Foetal Neonatal Med 2007 Feb;12(1):78-86.

(9) Ong KK. Size at birth, postnatal growth and risk of obesity. Horm Res 2006;65 Suppl 3:65-9.

(10) Cripps RL, Martin-Gronert MS, Ozanne SE. Foetal and perinatal programming of appetite. Clin Sci (Lond) 2005 Jul;109(1):1-11.

(11) McMillen IC, Maclaughlin SM, Muhlhausler BS, Gentili S, Duffield JL, Morrison JL. Developmental origins of adult health and disease: the role of periconceptional and foetal nutrition. Basic Clin Pharmacol Toxicol 2008 Feb;102(2):82-9.

(12) Black RE, Allen LH, Bhutta ZA, Caulfield LE, de OM, Ezzati M, et al. Maternal and child undernutrition: global and regional exposures and health consequences. Lancet 2008 Jan 19;371(9608):243-60.

(13) Tracking progress on child and maternal nutrition: A survival and development priority. UNICEF 2009:10-23. Available from: URL: http://www.unicef.org/publications/files/Tracking_Progress_on_Child_and_Maternal_Nutrition_EN_110309.pdf

(14) The state of Africa's children: Child survival. UNICEF 2008:10. Available from: URL: http://www.unicef.org/publications/files/SOAC_2008_EN.pdf

(15) Popkin BM. The nutrition transition and its health implications in lower-income countries. Public Health Nutr 1998 Mar;1(1):5-21.

(16) Jinabhai CC, Taylor M, Sullivan KR. Changing patterns of under- and over-nutrition in South African children-future risks of non-communicable diseases. Ann Trop Paediatr 2005 Mar;25(1):3-15.

(17) Kruger HS, Puoane T, Senekal M, van der Merwe MT. Obesity in South Africa: challenges for government and health professionals. Public Health Nutr 2005 Aug;8(5):491-500.

(18) Steyn NP, Labadarios D, Maunder E, Nel J, Lombard C. Secondary anthropometric data analysis of the National Food Consumption Survey in South Africa: the double burden. Nutrition 2005 Jan;21(1):4-13.

(19) Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. BMJ 2000 May 6;320(7244):1240-3.

(20) Mamiro PS, Kolsteren P, Roberfroid D, Tatala S, Opsomer AS, Van Camp JH. Feeding practices and factors contributing to wasting, stunting, and iron-deficiency anaemia among 3-23-month old children in Kilosa district, rural Tanzania. J Health Popul Nutr 2005 Sep;23(3):222-30.

(21) Kramer MS, Guo T, Platt RW, Vanilovich I, Sevkovskaya Z, Dzikovich I, et al. Feeding effects on growth during infancy. J Pediatr 2004 Nov;145(5):600-5.

(22) Hamosh M. Bioactive factors in human milk. Pediatr Clin North Am 2001 Feb;48(1):69-86.

(23) Bartok CJ, Ventura AK. Mechanisms underlying the association between breastfeeding and obesity. Int J Pediatr Obes 2009;4(4):196-204.

(24) Ailhaud G, Massiera F, Weill P, Legrand P, Alessandri JM, Guesnet P. Temporal changes in dietary fats: role of n-6 polyunsaturated fatty acids in excessive adipose tissue development and relationship to obesity. Prog Lipid Res 2006 May;45(3):203-36.

(25) Oddy WH, Sly PD, de Klerk NH, Landau LI, Kendall GE, Holt PG, et al. Breast feeding and respiratory morbidity in infancy: a birth cohort study. Arch Dis Child 2003 Mar;88(3):224-8.

(26) Dewey KG. Infant nutrition in developing countries: what works? Lancet 2005 May 28;365(9474):1832-4.

(27) WHO. Complementary feeding: report of the global consultation, and summary of guiding principles for complementary feeding of the breastfed child. WHO 2002:1-2. Available from: URL: http://whqlibdoc.who.int/publications/2002/924154614X.pdf

(28) Hatloy A, Hallund J, Diarra MM, Oshaug A. Food variety, socioeconomic status and nutritional status in urban and rural areas in Koutiala (Mali). Public Health Nutr 2000 Mar;3(1):57-65.

(29) Arimond M, Ruel MT. Dietary diversity is associated with child nutritional status: evidence from 11 demographic and health surveys. J Nutr 2004 Oct;134(10):2579-85.

(30) de Onis M. Measuring nutritional status in relation to mortality. Bull World Health Organisation. 2000;78(10):1271-4.

(31) Vesel L, Bahl R, Martines J, Penny M, Bhandari N, Kirkwood BR. Use of new World Health Organization child growth standards to assess how infant malnutrition relates to breastfeeding and mortality. Bull World Health Organ 2010 Jan;88(1):39-48.

(32) Chumlea WC, Schubert CM, Reo NV, Sun SS, Siervogel RM. Total body water volume for white children and adolescents and anthropometric prediction equations: the Fels Longitudinal Study. Kidney Int 2005 Nov;68(5):2317-22.

(33) Pietrobelli A, Boner AL, Tato L. Adipose tissue and metabolic effects: new insight into measurements. Int J Obes (Lond) 2005 Sep;29 Suppl 2:S97-100.

(34) Chumlea WC. Physical growth and maturation. In: Samour PQ, King K, editors. Handbook of Paediatric Nutrition. 3rd edition ed. London: Jones and Bartlett; 2005. p. 1-11.

(35) Cooper C. Epidemiology of osteoporotic fracture: looking to the future. Rheumatology (Oxford) 2005 Dec;44 Suppl 4:iv36-iv40.

(36) Heaney RP, Abrams S, Dawson-Hughes B, Looker A, Marcus R, Matkovic V, et al. Peak bone mass. Osteoporos Int 2000;11(12):985-1009.

(37) Barker DJ. The foetal and infant origins of disease. Eur J Clin Invest 1995 Jul;25(7):457-63.

(38) Gluckman PD, Hanson MA, Spencer HG. Predictive adaptive responses and human evolution. Trends Ecol Evol 2005 Oct;20(10):527-33.

(39) Bateson P, Barker D, Clutton-Brock T, Deb D, D'Udine B, Foley RA, et al. Developmental plasticity and human health. Nature 2004 Jul 22;430(6998):419-21.

(40) Lucas A. Role of nutritional programming in determining adult morbidity. Arch Dis Child 1994 Oct;71(4):288-90.

(41) Desai M, Crowther NJ, Ozanne SE, Lucas A, Hales CN. Adult glucose and lipid metabolism may be programmed during foetal life. Biochem Soc Trans 1995 May;23(2):331-5.

(42) Hales CN, Barker DJ. Type 2 (non-insulin-dependent) diabetes mellitus: the thrifty phenotype hypothesis. Diabetologia 1992 Jul;35(7):595-601.

(43) Waterland RA, Jirtle RL. Early nutrition, epigenetic changes at transposons and imprinted genes, and enhanced susceptibility to adult chronic diseases. Nutrition 2004 Jan;20(1):63-8.

(44) Wells JC. The thrifty phenotype hypothesis: thrifty offspring or thrifty mother? J Theor Biol 2003 Mar 7;221(1):143-61.

(45) Wells JC. Is early development in humans a predictive adaptive response anticipating the adult environment? Trends Ecol Evol 2006 Aug;21(8):424-5.

(46) Desai M, Byrne CD, Zhang J, Petry CJ, Lucas A, Hales CN. Programming of hepatic insulin-sensitive enzymes in offspring of rat dams fed a protein-restricted diet. Am J Physiol 1997 May;272(5 Pt 1):G1083-G1090.

(47) Clark PM. Programming of the hypothalamo-pituitary-adrenal axis and the foetal origins of adult disease hypothesis. Eur J Pediatr 1998 Jan;157 Suppl 1:S7-10.

(48) Gillman MW, Rifas-Shiman SL, Camargo CA, Jr., Berkey CS, Frazier AL, Rockett HR, et al. Risk of overweight among adolescents who were breastfed as infants. JAMA 2001 May 16;285(19):2461-7.

(49) Koletzko B. Long-term consequences of early feeding on later obesity risk. Nestle Nutr Workshop Ser Pediatr Program 2006;58:1-18.

(50) Fewtrell MS, Williams JE, Singhal A, Murgatroyd PR, Fuller N, Lucas A. Early diet and peak bone mass: 20 year follow-up of a randomized trial of early diet in infants born preterm. Bone 2009 Jul;45(1):142-9.

(51) Toschke AM, Martin RM, von KR, Wells J, Smith GD, Ness AR. Infant feeding method and obesity: body mass index and dual-energy X-ray absorptiometry measurements at 9-10 y of age from the Avon Longitudinal Study of Parents and Children (ALSPAC). Am J Clin Nutr 2007 Jun;85(6):1578-85.

(52) Jones G, Riley M, Dwyer T. Breastfeeding in early life and bone mass in prepubertal children: a longitudinal study. Osteoporos Int 2000;11(2):146-52.

(53) Petruschke T, Rohrig K, Hauner H. Transforming growth factor beta (TGF-beta) inhibits the differentiation of human adipocyte precursor cells in primary culture. Int J Obes Relat Metab Disord 1994 Aug;18(8):532-6.

(54) Foote KD, Marriott LD. Weaning of infants. Arch Dis Child 2003 Jun;88(6):488-92.

(55) Euser AM, Finken MJ, Keijzer-Veen MG, Hille ET, Wit JM, Dekker FW. Associations between prenatal and infancy weight gain and BMI, fat mass, and fat distribution in young adulthood: a prospective cohort study in males and females born very preterm. Am J Clin Nutr 2005 Feb;81(2):480-7.

(56) Ekelund U, Ong KK, Linne Y, Neovius M, Brage S, Dunger DB, et al. Association of weight gain in infancy and early childhood with metabolic risk in young adults. J Clin Endocrinol Metab 2007 Jan;92(1):98-103.

(57) Sayer AA, Syddall HE, Dennison EM, Gilbody HJ, Duggleby SL, Cooper C, et al. Birth weight, weight at 1 y of age, and body composition in older men: findings from the Hertfordshire Cohort Study. Am J Clin Nutr 2004 Jul;80(1):199-203.

(58) Victora CG, Sibbritt D, Horta BL, Lima RC, Cole T, Wells J. Weight gain in childhood and body composition at 18 years of age in Brazilian males. Acta Paediatr 2007 Feb;96(2):296-300.

(59) Sachdev HS, Fall CH, Osmond C, Lakshmy R, Dey Biswas SK, Leary SD, et al. Anthropometric indicators of body composition in young adults: relation to size at birth and serial measurements of body mass index in childhood in the New Delhi birth cohort. Am J Clin Nutr 2005 Aug;82(2):456-66.

(60) Martins PA, Hoffman DJ, Fernandes MT, Nascimento CR, Roberts SB, Sesso R, et al. Stunted children gain less lean body mass and more fat mass than their non-stunted counterparts: a prospective study. Br J Nutr 2004 Nov;92(5):819-25.

(61) Gale CR, Martyn CN, Kellingray S, Eastell R, Cooper C. Intrauterine programming of adult body composition. J Clin Endocrinol Metab 2001 Jan;86(1):267-72.

(62) Wells JC, Hallal PC, Wright A, Singhal A, Victora CG. Foetal, infant and childhood growth: relationships with body composition in Brazilian boys aged 9 years. Int J Obes (Lond) 2005 Oct;29(10):1192-8.

(63) Cooper C, Fall C, Egger P, Hobbs R, Eastell R, Barker D. Growth in infancy and bone mass in later life. Ann Rheum Dis 1997 Jan;56(1):17-21.

(64) Gigante DP, Victora CG, Horta BL, Lima RC. Undernutrition in early life and body composition of adolescent males from a birth cohort study. Br J Nutr 2007 May;97(5):949-54.

(65) Walker SP, Gaskin PS, Powell CA, Bennett FI. The effects of birth weight and postnatal linear growth retardation on body mass index, fatness and fat distribution in mid and late childhood. Public Health Nutr 2002 Jun;5(3):391-6.

(66) Griffiths PL, Rousham EK, Norris SA, Pettifor JM, Cameron N. Socio-economic status and body composition outcomes in urban South African children. Arch Dis Child 2008 Oct;93(10):862-7.

(67) Boot AM, de Ridder MA, Pols HA, Krenning EP, de Muinck Keizer-Schrama SM. Bone mineral density in children and adolescents: relation to puberty, calcium intake, and physical activity. J Clin Endocrinol Metab 1997 Jan;82(1):57-62.

(68) Travers SH, Jeffers BW, Bloch CA, Hill JO, Eckel RH. Gender and Tanner stage differences in body composition and insulin sensitivity in early pubertal children. J Clin Endocrinol Metab 1995 Jan;80(1):172-8.

(69) Yach D, Cameron N, Padayachee N, Wagstaff L, Richter L, Fonn S. Birth to ten: child health in South Africa in the 1990s. Rationale and methods of a birth cohort study. Paediatr Perinat Epidemiol 1991 Apr;5(2):211-33.

(70) Richter L, Norris S, Pettifor J, Yach D, Cameron N. Cohort Profile: Mandela's children: the 1990 Birth to Twenty study in South Africa. Int J Epidemiol 2007 Jun;36(3):504-11.

(71) Steyn NP, Nel JH, Nantel G, Kennedy G, Labadarios D. Food variety and dietary diversity scores in children: are they good indicators of dietary adequacy? Public Health Nutr 2006 Aug;9(5):644-50.

(72) Hatloy A, Torheim LE, Oshaug A. Food variety--a good indicator of nutritional adequacy of the diet? A case study from an urban area in Mali, West Africa. Eur J Clin Nutr 1998 Dec;52(12):891-8.

(73) Richter LM, Norris SA, De WT. Transition from Birth to Ten to Birth to Twenty: the South African cohort reaches 13 years of age. Paediatr Perinat Epidemiol 2004 Jul;18(4):290-301.

(74) WHO Anthro (version 3.1, June 2010) and macros [computer program]. 2010.

(75) de Onis M, Garza C, Onyango AW, Rolland-Cachera MF. [WHO growth standards for infants and young children]. Arch Pediatr 2009 Jan;16(1):47-53.

(76) Ellis KJ, Shypailo RJ, Pratt JA, Pond WG. Accuracy of dual-energy x-ray absorptiometry for body-composition measurements in children. Am J Clin Nutr 1994 Nov;60(5):660-5.

(77) Tanner JM, Whitehouse RH. Clinical longitudinal standards for height, weight, height velocity, weight velocity, and stages of puberty. Arch Dis Child 1976 Mar;51(3):170-9.

(78) Van den Broeck J, Cunningham SA, Eeckels R, Herbst K. Data cleaning: detecting, diagnosing, and editing data abnormalities. PLoS Med 2005 Oct;2(10):e267.

(79) Aiello AE, Larson EL. What is the evidence for a causal link between hygiene and infections? Lancet Infect Dis 2002 Feb;2(2):103-10.

(80) Hong R, Banta JE, Betancourt JA. Relationship between household wealth inequality and chronic childhood under-nutrition in Bangladesh. Int J Equity Health 2006;5:15.

(81) Cameron N, Wright MM, Griffiths PL, Norris SA, Pettifor JM. Stunting at 2 years in relation to body composition at 9 years in African urban children. Obes Res 2005 Jan;13(1):131-6.

(82) Cohen-Bendahan CC, Buitelaar JK, van Goozen SH, Cohen-Kettenis PT. Prenatal exposure to testosterone and functional cerebral lateralization: a study in same-sex and opposite-sex twin girls. Psychoneuroendocrinology 2004 Aug;29(7):911-6.

(83) Grumbach MM. The neuroendocrinology of human puberty revisited. Horm Res 2002;57 Suppl 2:2-14.

(84) Marild S, Hansson S, Jodal U, Oden A, Svedberg K. Protective effect of breastfeeding against urinary tract infection. Acta Paediatr 2004 Feb;93(2):164-8.

(85) Victora CG, Matijasevich A, Santos IS, Barros AJ, Horta BL, Barros FC. Breastfeeding and feeding patterns in three birth cohorts in Southern Brazil: trends and differentials. Cad Saude Publica 2008;24 Suppl 3:S409-S416.

(86) Wells JC. The evolution of human fatness and susceptibility to obesity: an ethological approach. Biol Rev Camb Philos Soc 2006 May;81(2):183-205.

(87) Scott JA, Binns CW. Breastfeeding: are boys missing out? Birth 1999 Dec;26(4):276-7.

(88) Arimond M, Ruel MT. Dietary diversity is associated with child nutritional status: evidence from 11 demographic and health surveys. J Nutr 2004 Oct;134(10):2579-85.

(89) Steyn NP, Nel JH, Nantel G, Kennedy G, Labadarios D. Food variety and dietary diversity scores in children: are they good indicators of dietary adequacy? Public Health Nutr 2006 Aug;9(5):644-50.

(90) Taylor RW, Grant AM, Williams SM, Goulding A. Sex differences in regional body fat distribution from pre- to postpuberty. Obesity (Silver Spring) 2010 Jul;18(7):1410-6.

(91) Herd SL, Gower BA, Dashti N, Goran MI. Body fat, fat distribution and serum lipids, lipoproteins and apolipoproteins in African-American and Caucasian-American prepubertal children. Int J Obes Relat Metab Disord 2001 Feb;25(2):198-204.

(92) He Q, Karlberg J. Bmi in childhood and its association with height gain, timing of puberty, and final height. Pediatr Res 2001 Feb;49(2):244-51.

(93) Cooper C, Fall C, Egger P, Hobbs R, Eastell R, Barker D. Growth in infancy and bone mass in later life. Ann Rheum Dis 1997 Jan;56(1):17-21.

(94) Jones G, Dwyer T. Bone mass in prepubertal children: gender differences and the role of physical activity and sunlight exposure. J Clin Endocrinol Metab 1998 Dec;83(12):4274-9.

(95) Butte NF, Wong WW, Hopkinson JM, Smith EO, Ellis KJ. Infant feeding mode affects early growth and body composition. Pediatrics 2000 Dec;106(6):1355-66.

(96) Davis JN, Weigensberg MJ, Shaibi GQ, Crespo NC, Kelly LA, Lane CJ, et al. Influence of breastfeeding on obesity and type 2 diabetes risk factors in Latino youth with a family history of type 2 diabetes. Diabetes Care 2007 Apr;30(4):784-9.

(97) Harvey NC, Robinson SM, Crozier SR, Marriott LD, Gale CR, Cole ZA, et al. Breast-feeding and adherence to infant feeding guidelines do not influence bone mass at age 4 years. Br J Nutr 2009 Sep;102(6):915-20.

(98) Godfrey KM, Barker DJ. Foetal nutrition and adult disease. Am J Clin Nutr 2000 May;71(5 Suppl):1344S-52S.

(99) Rogers IS, Ness AR, Steer CD, Wells JC, Emmett PM, Reilly JR, et al. Associations of size at birth and dual-energy X-ray absorptiometry measures of lean and fat mass at 9 to 10 y of age. Am J Clin Nutr 2006 Oct;84(4):739-47.

(100) Adair LS. Size at birth and growth trajectories to young adulthood. Am J Hum Biol 2007 May;19(3):327-37.

(101) Kuzawa CW. Foetal origins of developmental plasticity: are foetal cues reliable predictors of future nutritional environments? Am J Hum Biol 2005 Jan;17(1):5-21.

(102) Cooper C, Cawley M, Bhalla A, Egger P, Ring F, Morton L, et al. Childhood growth, physical activity, and peak bone mass in women. J Bone Miner Res 1995 Jun;10(6):940-7.

(103) Singhal A, Wells J, Cole TJ, Fewtrell M, Lucas A. Programming of lean body mass: a link between birth weight, obesity, and cardiovascular disease? Am J Clin Nutr 2003 Mar;77(3):726-30.

(104) Sachdev HS, Fall CH, Osmond C, Lakshmy R, Dey Biswas SK, Leary SD, et al. Anthropometric indicators of body composition in young adults: relation to size at birth and serial measurements of body mass index in childhood in the New Delhi birth cohort. Am J Clin Nutr 2005 Aug;82(2):456-66.

(105) Gigante DP, Horta BL, Lima RC, Barros FC, Victora CG. Early life factors are determinants of female height at age 19 years in a population-based birth cohort (Pelotas, Brazil). J Nutr 2006 Feb;136(2):473-8.

(106) Barker DJ. The long-term outcome of retarded foetal growth. Schweiz Med Wochenschr 1999 Feb 6;129(5):189-96.

(107) Sayer AA, Cooper C. Foetal programming of body composition and musculoskeletal development. Early Hum Dev 2005 Sep;81(9):735-44.

(108) Fewtrell MS, Morley R, Abbott RA, Singhal A, Stephenson T, MacFadyen UM, et al. Catch-up growth in small-for-gestational-age term infants: a randomized trial. Am J Clin Nutr 2001 Oct;74(4):516-23.

(109) Sawaya AL, Roberts S. Stunting and future risk of obesity: principal physiological mechanisms. Cad Saude Publica 2003;19 Suppl 1:S21-S28.

(110) Volpe EM, Bear M. Enhancing breastfeeding initiation in adolescent mothers through the Breastfeeding Educated and Supported Teen (BEST) Club. J Hum Lact 2000 Aug;16(3):196-200.

(111) Infant and young child nutrition: Global strategy on infant and young child feeding. WHO 2002:5-7. Available from: URL: http://apps.who.int/gb/archive/pdf_files/WHA55/ea5515.pdf

(112) Crozier SR, Inskip HM, Godfrey KM, Robinson SM. Dietary patterns in pregnant women: a comparison of food-frequency questionnaires and 4 d prospective diaries. Br J Nutr 2008 Apr;99(4):869-75.

(113) Bingham SA, Day NE, Luben R, Ferrari P, Slimani N, Norat T, et al. Dietary fibre in food and protection against colorectal cancer in the European Prospective Investigation into Cancer and Nutrition (EPIC): an observational study. Lancet 2003 May 3;361(9368):1496-501.

(114) Barker DJ. Developmental origins of adult health and disease. J Epidemiol Community Health 2004 Feb;58(2):114-5.

APPENDICES

Appendix 1: Retrospective Food frequency questionnaire for one-year old infants from Birth-Twenty study cohort

1

FOOD FREQUENCY QUESTIONNAIRE

Childs name.....Thandekile Duma..... Ref. No.4731670
Sex.F.. Ethnic group...Black.. Clinic.....DH..... Date of birth.....

Please determine/calculate how often your child consumes each of the food items mentioned below and indicate by means of a (X) in the appropriate frequency column. When letters are indicated in brackets alongside the food item, please use the letter in the appropriate frequency column to indicate which item/s are consumed.
* When an item is consumed more than 2/day indicate the number in the column.

FOOD ITEM	SELDOM NEVER	1/MTH	2-3/MTH	1/WK	2-4/WK	5-6/wk	1/dy	*2/dy MORE
BEVERAGES								
Milk (full cream(F)								
skimmed(S),low fat(LF)								
other - state								
squash/cordial								
carbonated beverages:								
sugar added				tea				
sugar free,								
Game(Isotonic)								
tea								
coffee								
milo(M),horlicks(H),								
cocoa(C),other - state								
CEREALS AND PORRIDGES								
sweetened cereal								
rice krispies(RK),								
cornflakes(C),								
all bran(A),								
weetbix(W),								
pronutro(P),								
oats(O),maltabella(M),							MM	
mieliemeal-soft(MM),								
other - state								
BREAD, BISCUITS								
Bread white(W),brown(B)							2	
wholewheat(WW)								
crispbreads provita(P),								
cream crackers(CR)								
other - state								
SPREADS							M	
margarinr(M),butter(B),								
peanut butter(PB),								
jam(J),								
marmite(MR),								
fish paste(FP),								
bovril(BR)								
other - state								

REF. NO. .....

FOOD ITEM	SELDOM NEVER	1/MTH	2-3/MTH	1/WK	2-4/wk	5-6/wk	1/dy	*2/dy MORE
CAKES, PUDDINGS, SNACKS								
cake(C),pastries(P),								
scone(S),doughnut(D),								
biscuits-plain(P)				P				
-filled(F)								
tarts-jam(J),milk(M)					C			
ice-cream								
custard					J			
jelly								
baked pudding								
instant pudding								
cream								
crisps								
peanuts								
popcorn								
SUGAR, SWEETS, CHOCOLATES								
sugar								
sweets-sucking(S),								
jelly(J),								
toffees(T),								
chocolate-plain(P)							P	
-bar(B)							F	
PROTEIN SOURCES								
yoghurt-plain(P),								
flavoured(F)								
beef-steak								
-stew,curry								
-roast								
-mince				M				
-meatballs								
-cottge pie								
-spaghetti								
bolognaise								
-sausage								
-pie								
mutton-chops								
-stew,curry								
-roast								
pork-chops								
-stew,casserole								
-roast								
-sausage								
-sausage roll								
-boerewors								
-vienna								
-polony								
-ham								
-bacon								
chicken-stew,curry								
-roast								
-pie								
gravy								
Eggs								

REF. NO. .....

FOOD ITEM	SELDOM NEVER	1/MTH	2-3/MTH	1/WK	2-4/WK	5-6/wk	1/dy	*2/dy MORE
cheese-cheddar(CH),								
gouda(G)								
cottage(C)								
pizza								
macaroni cheese								
fish-hake-fried(F),								
-baked(B)								
-pie(P)								
Tuna salad								
pilchards(P),sardines(S)				P				
STARCHES								
rice(R),pasta(P),								
mieliemeal-stiff								
samp/mielierice								
mielies								
FRUIT								
average fresh fruit				J				
juice							A	
average fresh fruit								
apple(A),banana(B),							B	
orange(O)							O	
tinned fruit								
dried fruit-prunes								
mixed(M),raisins(R)								
VEGETABLES								b
potatoes-boiled								
-baked								
-mashed								m
-roast								
-chips								
average green vegetable				J				
average yellow/red veg				R				
average white vegetable								
dried vegetables-beans				W				
-lentils								
baked beans								
salad-green(S)								
tomatoes-raw(R),cooked(C)								
SAUCES								
white sauce								
cheese sauce								
mayonnaise								
salad dressing								
mustard								
chutney								
tomato sauce								
OIL							O	
SOUP								
homemade(H),tinned(T)							H	

Appendix 2: Food groups of 149 food items consumed by infants in the FFQ.

Food groups	Food item in the FFQ
1. Meat/poultry/fish	• **Beef**: minced, steak, meatballs, roasted, stew, curry, cottage pie, game isotonic, mutton roast, mutton chops, mutton stew, bolognaise sausage • **Chicken**: stew, roasted, pie, curry • **Fish**: paste, pie, fried, baked, other fish • **Pork**: boerewors, polony, vienna, sausage roll, stew, pork chops, roast, bacon, ham, sausages (32)
2. Grains/cereals/cereal/ other starch products	Oats, samp, mealies, maltabella, mealie-meal soft/stiff porridge, rice, pasta, pizza, bread (whole-wheat/white/brown),biscuits(fitted, plain or other), mealie meal, Weetabix, Pro-vita, rice krispies, cornflakes, all bran, cake, popcorn, scones, pastry, doughnuts, macaroni cheese, bolognaise pie, cream crackers, mealie rice, other starch, other cereals (33)
3. Dairy/dairy products	Full cream/low fat/skimmed milk, cream, yoghurt (plain or flavoured), cheese(cheddar, gouda, cottage), ice cream, milk shack, other milk types (12)
4. Legumes/nuts/legume	Baked beans, dried vegetable beans, lentils,

products	peanuts, dried beans, dried lentils (6)
5. Vitamin A rich vegetables (green/yellow/red vegetables)	Squash, tomatoes, green/tuna salad (4)
6. Other vegetables	Potatoes(chips/ roasted/boiled/baked) and potato crispies, other vegetables (6)
7. Fats and oils	Margarine, butter, peanut butter, oil (3)
8. Fruits	Apples, banana, orange, mixed fruits, raisins, tinned fruit, fruit juices, dried raisins, mixed dried prunes, other fruits (11)
9. Sugars	Squash/cordial drinks, jam, sweets sucking, instant pudding, baked pudding, custard , jelly, chocolate bar, tart jam, carbonated beverage with sugar (11)
10. Eggs	Eggs (average white/yellow) (1)
11. Miscellaneous	Soup, coffee, tea, gravy, homemade soup, tomato sauce, other soups, mayonnaise, white sauce, marmite, carbonated beverages without sugar, mustard sauce, salad dressing, cocoa, Bovril, Milo, Horlicks, other snacks, other beverages, toffee (21)

Appendix 3: Ethics clearance certificate.

mjM0
UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

Division of the Deputy Registrar (Research)

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)
R14/49 Mrs Juliana Kagura

CLEARANCE CERTIFICATE	**M090420**
PROJECT	The Association between Infant Nutrition and Later Body Composition
INVESTIGATORS	Mrs Juliana Kagura.
DEPARTMENT	Department of Paedaitrics
DATE CONSIDERED	09.04.29
DECISION OF THE COMMITTEE*	Approved unconditionally

Unless otherwise specified this ethical clearance is valid for 5 years and may be renewed upon application.

DATE 09.04.29 **CHAIRPERSON** .....
(Professor P E Cleaton Jones)

*Guidelines for written 'informed consent' attached where applicable

cc: Supervisor : Dr S Norris

DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and **ONE COPY** returned to the Secretary at Room 10004, 10th Floor, Senate House, University.
I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee. **I agree to a completion of a yearly progress report.**

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES...
.....

Appendix 4: Description of study variables

1. EARLY LIFE VARIABLES	DESCRIPTION
A) Growth	
Gestational age	The period of the pregnancy in weeks
Birth weight	The weight of the child at birth in grams
Yr 1/2 weight	Weight in kilograms at ages 1 and 2
Yr 1/2 height	Weight in kilograms at ages 1 and 2
Yr 1/2 Stunting	Low height for-age z-score (HAZ) or stunting is defined as more than 2 standard deviations below the median value of the WHO International Growth Reference for length or height-for-age.
Yr 1/2 Underweight	Low weight for-age z-score (WAZ) or underweight is defined as more than 2 SD below the WHO international growth reference weight-for-age median.
Yr 1/2 Wasting	Low weight for-height z-score (WHZ) or wasting is defined as more than 2 SD below the WHO international growth reference weight-for-height median.
B) Nutrition	
Breastfeeding	Duration in months of breastfeeding
Bottle feeding	Duration in months of bottle feeding
Complementary feeding	Month at which solids were introduced
Dietary diversity score	The number of food groups consumed over a period of twenty four hours
Food variety score	The number of food items consumed over a twenty hour period
C) Socio-demographic variables	
Maternal age	The age of the biological mother at the birth of the child
Gender	The sex of the child: 1=male, 2=female
Ethnicity	The ethnicity of the child: 1=white,2=black, 3=coloured, 4=Asian

Maternal education	Biological mothers level of education at birth: 1=no formal education, 2=≤std3/≤Gr5, 3=std4-5/Gr6-7,4=std 6-8/Gr11-12,6=post school training
Marital status	What was the mother's marital status at the time of the birth: 1=married,2=living together,3=separated/divorced/widowed,4=single
Gravidity	Number of *pregnancies* (alive or not alive births)
Parity	The condition of *giving birth* to (alive or not alive)
House type	Type of home: 1=shack,2=flat,3=house,4=hostel,5=shared house,6=room,7=garage
House ownership	Description of the home: 1 = Owned, 2 = Rented another person, 3 = Rental local authority, 4 = Provided employer
SES-water type	Water source type: 1 = Indoor running hot and cold, 2 = Indoor running cold water, 3 = Tap outside the house, 4 = Water from other source
SES-water use	Water usage: 1 = Sole Usage, 2 = Shared, 3 = No Access
d) Yr 9, 10 variables Fat mass(g)	Total fat mass excluding the head in grams
Lean mass (g)	Total lean mass excluding head in grams
Whole body (BMC/BA)	Whole body excluding the head
lumbar spine (BMC/BA)	Lumbar spine from the L1 to L4
Femoral neck (BMC/BA)	Hip neck measurement
Radius (BMC/BA)	1/3 radius measurement
Tanner stage	A stage of pubertal development as estimated by the Tanner growth charts showing pubic hair (1) for both sexes, genitalia for boys and breasts for girls (2)

Appendix 5: Association between early life factors and body composition at age 9/10 years

Variable	Fat mass	Lean mass	Whole body	Radius	Femur	Lumbar spine
At birth						
Birth weight z-score	0.06(-0.02-0.13) 0.140	0.05(0.02-0.08) **0.000***	0.04(-0.01-0.08) 0.104	0.04(0.02-0.07) **0.000***	0.04(0.01-0.07) **0.002***	0.05(0.02-0.08) **0.001***
Infant nutrition						
Breastfeeding duration	0.01(-0.003- -0.017) 0.162	-0.002(-0.005-0.02) 0.364	-0.002(-0.004-0.01) 0.583	-0.002(-0.005-0.001) 0.191	-0.003(-0.01-0.001) 0.069	0.002(-0.002-0.005) 0.381
Bottle-feeding duration	-0.01(-0.028-0.002) 0.096	-0.003(-0.01-0.03) 0.342	-0.003(-0.01-0.01) 0.478	-0.0004(0.005-0.004) 0.863	-0.003(-0.009-0.003) 0.283	-0.002(-0.01-0.003) 0.412
Introduction of solids	0.02(-0.05-0.09) 0.516	-0.001(-0.02-0.02) 0.960	0.03(-0.01-0.07) 0.083	-0.001(-0.02-0.02) 0.929	0.003(-0.02-0.03) 0.792	-0.01(-0.03-0.02) 0.533
Dietary diversity score	0.01(-0.08-0.09) 0.902	0.001(-0.03-0.03) 0.941	0.02(-0.03-0.07) 0.372	-0.01(-0.03-0.02) 0.517	-0.02(-0.05-0.01) 0.464	0.02(-0.02-0.05) 0.317
Food variety score	-0.03(-0.14-0.09) 0.651	-0.01(-0.05-0.03) 0.628	0.01(-0.05-0.08) 0.665	-0.03(-0.06-0.01) 0.110	-0.04(-0.08-0.001) **0.043***	-0.01(-0.06-0.03) 0.587
Infant growth						
Age Yr1:						
Weight	0.16(0.09-0.23) **0.000***	0.07(0.05-0.10) **0.000***	0.09(0.04-0.13) **0.000***	0.05(0.02-0.07) **0.000***	0.06(0.04-0.09) **0.000***	0.07(0.04-0.10) **0.000***
Height	0.09(0.01-0.16) **0.025***	0.06(0.03-0.09) **0.000***	0.06(0.02-0.12) **0.004***	0.04(0.01-0.06) **0.002***	0.06(0.04-0.09) **0.000***	0.06(0.03-0.08) **0.000***
Stunting Normal Stunted	 1 -0.37(-0.64-0.10) **0.008***	 1 -0.12(-0.21-0.02) **0.018***	 1 -0.22(-0.37- -0.07) **0.005***	 1 -0.08(-0.16-0.005) 0.066	 1 -0.12(-0.20- -0.01) **0.028***	 1 -0.17(-0.27-0.07) **0.001***
Wasting Normal Wasted	 1 -0.10(-0.52-0.32) 0.635	 1 -0.10(-0.25-0.05) 0.183	 1 -0.21(-0.44-0.03) 0.080	 1 -0.10(-0.22-0.02) 0.110	 1 -0.04(-0.19-0.10) 0.558	 1 -0.18(-0.35- -0.02) **0.026***
Underweight Normal Underweight	 1 -0.23(-0.50-0.05) 0.106	 1 -0.11(-0.21- -0.02) **0.024***	 1 -0.25(-0.40-0.10) **0.002***	 1 -0.10(-0.18-0.02) **0.016***	 1 -0.06(-0.16-0.04) 0.229	 1 -0.20(-0.30- -0.10) **0.000***
Age Yr2						

Weight	0.16(0.09-0.23) **0.000***	0.07(0.05-0.10) **0.000***	0.08(0.04-0.12) **0.000***	0.03(0.004-0.05) **0.023***	0.05(0.02-0.07) **0.000***	0.05(0.03-0.08) **0.000***
Height	0.06(-0.01-0.14) 0.105	0.07(0.04-0.09) **0.000***	0.06(0.02-0.10) **0.008***	0.04(0.01-0.06) **0.001***	0.05(0.03-0.08) **0.000***	0.06(0.04-0.09) **0.000***
Stunting						
Normal	1	1	1	1	1	1
Stunted	-0.16(-0.37-0.05) 0.134	-0.12(-0.20- -0.05) **0.001***	-0.09(-0.21-0.03) 0.138	-0.07(-0.14- -0.01) **0.019***	-0.13(-0.20- -0.06) **0.001***	-0.16(-0.24- -0.08) **0.000***
Wasting						
Normal	1	1	1	1	1	1
Wasted	-0.19(-0.45- -0.08) 0.166	-0.07(-0.16-0.03) 0.190	-0.12(-0.28-0.03) 0.125	-0.04(-0.13-0.04) 0.287	-0.05(-0.15-0.05) 0.300	-0.06(-0.16-0.05) 0.271
Underweight						
Normal	1	1	1	1	1	1
Underweight	-0.24(-0.45- -0.04) **0.022***	-0.06(-0.14-0.01) 0.110	-0.11(-0.23-0.01) 0.073	-0.005(-0.07-0.06) 0.886	-0.02(-0.09-0.06) 0.686	-0.07(-0.15-0.01) 0.108
SES at birth						
Gravidity						
1	1	1	1	1	1	1
2+	-0.06(-0.22-0.09) 0.417	0.02(-0.03-0.08) 0.433	-0.05(-0.14-0.04) 0.263	0.02(-0.02-0.07) 0.304	0.03(-0.04-0.07) 0.526	0.003(-0.06-0.06) 0.901
Parity						
1	1	1	1	1	1	1
2+	-0.05(-0.21-0.10) 0.502	0.02(-0.03-0.08) 0.458	-0.03(-0.12-0.06) 0.519	0.01(-0.03-0.06) 0.537	0.03(-0.03-0.08) 0.293	0.03(-0.03-0.09) 0.334
Maternal age						
19-29	1	1	1	1	1	1
13-18	-0.07(-0.26-0.12) 0.463	-0.03(-0.10-0.04) 0.331	0.06(-0.05-0.17) 0.279	-0.02(-0.08-0.04) 0.448	-0.02(-0.09-0.05) 0.573	-0.02(-0.10-0.06) 0.637
30+	0.05(-0.16-0.25) 0.650	-0.03(-0.10-0.05) 0.467	-0.04(-0.15-0.08) 0.544	-0.04(-0.10-0.02) 0.167	-0.05(-0.12-0.02) 0.151	-0.04(-0.11-0.04) 0.372
Gender						
Male	1	1	1	1	1	1
Female	0.29(0.13-0.43) **0.000***	-0.04(-0.10-0.02) 0.189	0.04(-0.05-0.12) 0.409	-0.07(-0.12- -0.03) **0.002***	-0.14(-0.19- -0.09) **0.000***	0.06(0.00-0.11) 0.064
Marital status						
Married	1	1	1	1	1	1
Single	-0.07(-0.26-0.11) 0.449	0.01(-0.06-0.08) 0.757	0.02(-0.08-0.13) 0.691	-0.01(-0.07-0.04) 0.645	-0.003(-0.07-0.04) 0.914	-0.01(-0.08-0.06) 0.764
Maternal education						
≥std9	1	1	1	1	1	1
≤std8	-0.17(-0.32- -0.01) **0.034***	0.04(-0.10-0.02) 0.183	-0.03(-0.12-0.06) 0.508	-0.03(-0.08-0.01) 0.165	-0.02(-0.07-0.09) 0.477	-0.04(-0.10-0.02) 0.202
Gestational age						
≥39	1	1	1	1	1	1
≤38	-0.02(-0.20-0.24) 0.838	0.01(-0.10-0.07) 0.739	-0.02(-0.10-0.15) 0.727	-0.02(-0.04-0.09) 0.505	-0.01(-0.07-0.09) 0.723	-0.03(-0.06-0.11) 0.526
House type						
House	1	1	1	1	1	1
Other	0.18(-0.11-0.48) 0.225	0.03(-0.07-0.14) 0.537	0.07(-0.10-0.24) 0.427	-0.02(-0.11-0.07) 0.642	0.04(-0.06-0.15) 0.416	0.03(-0.06-0.11) 0.526
House ownership						
Owned	1	1	1	1	1	1
Other	-0.02(-0.18-0.13) 0.756	-0.01(-0.07-0.04) 0.598	-0.01(-0.10-0.08) 0.886	-0.03(-0.08-0.01) 0.146	-0.04(-0.09-0.02) 0.155	-0.02(-0.08-0.03) 0.419
Water type						
Indoor	1	1	1	1	1	1
Other	-0.03(-0.19-0.12) 0.690	0.01(-0.04-0.07) 0.692	-0.02(-0.11-0.07) 0.669	0.01(-0.04-0.06) 0.666	0.03(-0.03-0.08) 0.353	-0.01(-0.07-0.05) 0.832

Water usage						
Sole Usage	1	1	1	1	1	1
shared	0.11(-0.10-0.33) 0.288	0.01(-0.07-0.09) 0.787	0.05(-0.07-0.17) 0.143	0.01(-0.05-0.08) 0.654	0.06(-0.02-0.13) 0.142	0.05(-0.03-0.13) 0.191
Electricity						
Yes	1	1	1	1	1	1
No	-0.17(-0.70-0.36) 0.529	-0.06(-0.25-0.13) 0.526	-0.09(-0.39-0.22) 0.579	-0.13(-0.29-0.03) 0.101	0.04(-0.15-0.22) 0.707	-0.01(-0.21-0.20) 0.932