# Growth Analysis of Mixed Ancestry Infants Aged 0 – 18 months, South Africa

**by**

**LIESL MARGO ARENDSE**

**ARNLIE002**

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Supervisor : Associate Professor Victoria E. Gibbon

Co-Supervisors : Associate Professor Desiré Brits

Professor Estelle Victoria Lambert

# Declaration

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The original research idea was my own. My primary supervisor provided overall project supervision. Associate Professor Gibbon and I designed the research project based on the hypothesised outcome, and as primary supervisor she streamlined the research locations and number of participants to be included. All supervisors provided statistical guidance and editorial input. I conducted quantitative and qualitative data analyses with guidance and tutorials from Professor Lambert and Elizabeth Dinkele.

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## For Those Who Believed and Loved Me

I made it to the end because You Believed I could along the Journey when I didn’t.

Carmen, Khanya Danielle, Marian-Joan, Dad,
Rukaya, Thuraya, Charlene,
and my Dearly Beloved Departed Brother,
Nolan Peter Arendse.

*“I can almost see it*
*That dream I'm dreaming*
*But, there's a voice inside my head saying*
*You'll never reach it*

*Every step I'm taking*
…
*My faith is shaking*
…
*The struggles I'm facing*
*The chances I'm taking*
*Sometimes might knock me down, but*
*No, I'm not breaking*
…
*Just keep pushing on,*
…
*Ain't about how fast I get there*
*It's the climb”*

Miley Cyrus (2009)

Songwriters: Jessi Leigh Alexander / Jon Clifton Mabe

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# Conference presentations and publications

The following peer-reviewed conference presentation and publication manuscript were extensions of different research components this thesis encompassed. The publication manuscript represented the formulation of the research concept and was submitted in July 2020 prior to the virtual 90$^{th}$ Annual Meeting of the American Association of Physical Anthropology 2021 yet was only accepted after the conference in April 2021. We, as the authors, presented literature research and reasoning for possible differences within the South African Mixed Ancestry population in this manuscript. The conference presentation focussed on the age-standardised anthropometry for the study's infant cohort. At the conference, results were presented in poster format, and the panel discussion was based on growth abnormality prevalence rates.

## Conference presentation

Poster presentation at the virtual 90$^{th}$ Annual Meeting of the American Association of Physical Anthropology (Figure A.1, Appendix A). The virtual conference included a short 3-minute presentation by the candidate, and a 10-minute question and answer period. The abstract reference is as follows:

> Arendse, L.M., Brits, D., Lambert, V., Gibbon, V.E. 2021. Growth analysis of South African Mixed Ancestry infants. In: Program of the 90th Annual Meeting of the American Association of Physical Anthropologists. *American Journal of Physical Anthropology* 174: 5.
> Doi: 10.1002/ajpa.24262

## Publication

The article was submitted in July 2020, feedback from reviewers in December 2020, and then resubmitted with changes from reviewers in February 2021. It was accepted by the journal in April 2021 for publication in 2022 (Figure A.2, Appendix A).

> Arendse L M, Brits D, Lambert E V, Gibbon V. In press. Is the World Health Organization's multicentre child growth standard an appropriate growth reference for assessing optimal growth of South African Mixed Ancestry children? *South African Journal of Child Health* 16(2): in press.
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# List of Abbreviations

| | |
|---|---|
| AD | African descendent |
| AIDS | Acquired immunodeficiency syndrome |
| CHC | Community Health Centre |
| cm | Centimeter |
| EC | Eastern Cape province |
| ED | European descendent |
| GP | Gauteng province |
| HFIAS | Household food insecurity assess scale |
| HIV | Human immunodeficiency virus |
| km | Kilometre |
| KZN | Kwa-Zulu Natal province |
| LBW | Low birth weight |
| LP | Limpopo province |
| L-SES | Low socio-economic status |
| MA | Mixed ancestry |
| MGRS | Multicenter Growth Reference Study |
| MU-SES | Middle-upper socio-economic status |
| NC | Northern Cape province |
| NCD | Non-communicable disease |
| SA | South Africa |
| SAJCH | South African Journal of Child Health |
| SADHS | South African Demographic and Health Survey |
| SD | Standard deviation |
| SES | Socio-economic status |
| SGA | Small-for-gestational age |
| WC | Western Cape province |
| WHO | World Health Organization |

# Abstract

Early life nutritional status and subsequent growth trajectory may impact adult health status later in life. In South Africa, children of mixed ancestry (MA, 1-10 years) have a significantly higher risk for stunting (according to WHO growth standards) compared to other population groups. Adults of MA have the second highest type II diabetes mellitus prevalence, and hypertension doubled between 2008-2016. Insight into healthy MA infant growth may help to explain, in part, this pattern of adult-onset NCDs. This study aimed to document healthy MA infant growth, against the WHO growth standards, in a 0 – 18-month-old cohort. Regression analyses were used to investigate which socio-demographic and/or socio-economic factors related to age-standardised growth.

Recruited dyad pairs from three clinics (two public, one private) included 161 infants (boys=71, girls=90), divided into three six-month age groups. Standard nutritional anthropometry was conducted. Statistical associations between age-standardised z-scores with socio-demographic and socio-economic factors (recorded via questionnaires) were assessed, and subsequently used in regression modelling of age-standardised growth.

Infants under 6 months grouped between -2 SD and +1 SD for length, weight, and head circumference WHO z-scores; those over 6 months grouped between -1 SD and +2SD. Stunting was more prevalent in infants under six months, and overweight for infants over six months, with a higher prevalence in boys, including wasting. Stunting prevalence in this cohort was under 3%, much lower than the national prevalence reported as 27.5% (<5 years). Conversely, more than 6% were overweight/obese, similar to previous national prevalence (<5 years).

Positive significant contributors in regression models were maternal age and education for age-standardised length, weight, and head circumference; gestational age for length and head circumference; exclusive breastfeeding duration for head circumference only; household occupancy and age complementary foods were introduced, for length and weight; explaining some growth trajectory variance within this cohort.

Although most of these infants fell within the WHO growth standard norm, the negative age-standardised results for infants under six months may explain overweight/obesity prevalence in those over six months. This research contributes to the knowledge of populational growth differences of healthy full-term infants that may inform the aetiology of adult-onset NCDs. [350 words]

Date : 15-10-2022

# CHAPTER 1: INTRODUCTION

In South Africa (SA), the World Health Organization (WHO) Multicentre Growth Reference Study Group (MGRS) 2006's international growth standard is used to determine early life nutritional status (De Onis *et al*., 2006). Yet, previous research on infants from birth to age five based in various countries across the globe, for example. the Czech Republic, Central Europe, Japan, and China, has shown a population-specific deviation in children's growth patterns from the WHO MGRS international growth norms. These deviations may result in misdiagnosis of malnutrition in these populations (Fenn and Penny, 2008; Natale and Rajagapolan, 2014; Vignerová *et al*., 2015; Christesen *et al*., 2016; Inokuchi *et al*., 2018; Tian *et al*., 2019). As a result, some researchers recommended only using a national growth reference whereas others promoted use of a combination of the WHO standard and a national population-specific growth reference. Many stated that the decision to use either the WHO standard or a national population-specific references was dependent on how healthy children's nutritional status fared against these growth models. For example, Vignerová *et al*. (2015) found that 0 – 12-month-old Czech children who were breast fed, were both taller (above median or '0') and had head circumference measurements greater than the WHO standard. Conversely, Inokuchi *et al*. (2018) found that Japanese children were generally shorter than the WHO standard, and consequently underestimated overweight prevalence. Similarly, Reddy *et al*. (2020) reported that there was an overestimation of stunting and underweight prevalence of Indian infants under 2 years using the WHO standard. There seems to be a general agreement that stunting, underweight and wasting were overestimated, whereas overweight and obesity were underestimated using the WHO standards. One of the observations made by Natale and Rajagapolan (2014) was the possibility that misdiagnosis of malnutrition or growth disorders in individuals whose growth does not 'conform' to the WHO MGRS growth standard was far greater, and their subsequent treatment may lead to an additional burden of non-communicable diseases (NCDs) in later life. Singhal (2017) noted that optimal patterns of infant weight gain were likely to differ when considering small-for-gestational age (SGA) and low birth weight (LBW) in different populations. Singhal echoed the sentiments of Cameron and Demerath (2002) who stated that above average accelerated weight gain in healthy full-term infants, especially in a low- and middle-income country (LMIC), may in fact increase the risk of obesity and heighten the prevalence of NCDs such as hypertension and type II diabetes mellitus in adulthood.

It was not to say that the age-standardised WHO growth standard was completely inappropriate as a health-indicator tool, but rather that slight deviations at earlier infancy ages may have a ripple effect later on. This type of deviation could exist in SA, described as an LMIC with a high prevalence rate of the double burden of malnutrition (Black *et al*., 2013; Monyeki *et al*., 2015; Nyati *et al*., 2019; Senekal *et al*., 2019; Sartorius *et al*., 2020). If young children in SA are erroneously misdiagnosed against the WHO standard that set inappropriate early life growth goals, it may shed light on the high percentage of obesity in children under five, and the pattern of adult-onset NCDs.

SA has been described as a melting pot of cultures due to diverse ancestral heritage. With one of the highest levels of heterozygosity (30%) in the world, and intergenerational effects due to unique socio-political and socio-economic conditions, a unique mix of population groups was created in SA (Petersen *et al*., 2013; Busby *et al*., 2016; Montinaro *et al*., 2017). Consequently, these unique individuals may differ in growth rate and have deviations from the WHO standard norms.

The 2016 SA Demographic and Health Survey (SADHS) reported stunted growth (length/height-for-age z-scores < -2 standard deviation (SD) below the WHO standard norm (0)) for 1 in 3 boys, and 1 in 4 girls (De Onis and Branca, 2016; National Department of Health *et al*., 2017). If this is applied to South African children of mixed ancestry (MA), approximately 80 589 boys and 58 485 girls (self-calculated based on number of MA children) younger than 4 years are estimated to be stunted in this age cohort (Statistics South Africa, 2018). Furthermore, the SADHS reported that 24% and 13% of all South African children younger than 5 years in the middle and top wealth quintiles, respectively, were estimated to be stunted according to the WHO MGRS growth charts (National Department of Health *et al*., 2017). Conversely, the percentage children classified as overweight were twice the international average (6.1%) for the same age group.

If growth charts are to be used as a general health indicator of a population group, standardisation of population-specific growth models/charts may better inform health care policy development and regulate future preventative health care for population groups at risk (Christesen *et al*., 2016). With the intended roll out of a National Health Insurance Policy in the near future (Department of Health, 2017), it is imperative to understand the factors that affect linear growth. Previous SA research has focused on linear growth of MA infants, determinants of health, psychosocial development and micronutrient deficiencies, but none specified that only healthy infants (no chronic diseases or illnesses) were recruited. Those that did, combined data from two distinctive ancestral population groups, namely individuals of African Descent and Mixed Ancestry. Also, most MA research in the region specific to this study were in "disadvantaged" communities indicative of socio-economic inequities, a higher prevalence of nutrient-deficient disorders, and increased pathogen exposure such as tuberculosis and diarrhoea, impacting physical growth of infants, toddlers, children, and/or adolescents (Labadarios and Steyn, 2005; Akachi and Canning, 2007, Shisana *et al*., 2013). Research done by Ardington and Case (2009) showed a 5.0% and greater difference in stunting between wealth quintiles 1-2 (lower spectrum of per capita income) and 4-5 (highest spectrum of per capita income), though these results were of all population groups combined in South Africa in 2008. Underweight prevalence in wealth quintiles 1-2 were double that of the highest wealth quintiles 4-5 with only a 3.0% to 5% difference in overweight and obesity prevalence rates between these two groups. Overweight and obesity prevalence was higher in wealth quintiles 4-5. Wasting prevalence rate was higher by 20.0% in wealth quintile 4-5 than in wealth quintile 1-2.

The purpose of this study was and is important to determine if healthy, full-term MA infants deviate from the WHO standard norm and at what age did this occur, if at all. Consequently, the knowledge gained from this research may provide insight, in part, into the high prevalence of overweight/obesity and NCDs such as cardio-vascular diseases in SA. Furthermore, understanding which maternal and infant factors are associated with MA infant growth, may provide insight as to why there is, if any, a growth trajectory difference between MA infants and other population groups in SA.

Research-based information can and will promote greater understanding of why stunting, wasting and/or overweight/obesity prevalence in SA remains high when new policies to address these high prevalence rates had been implemented in South Africa to lower the prevalence rates. This research will add to the scientific knowledge needed to effectively monitor infant growth, and possibly contribute to understanding the high prevalence of adult-onset NCDs in this specific population group. Furthermore, research-based information helps to garner government support for new policy development and implementation as was done with the introduction in 2002 of free vitamin A booster drops for children aged 6 – 59 months at all government health care facilities.

Therefore, the aims of this study were to:

1. Collect baseline data for healthy, full-term MA infants aged 0 – 18 months from different socio-economic status (SES) locations in Cape Town that can be used by various people in different spheres of public health.
2. Analyse linear growth of healthy, full-term MA infants aged 0 – 18 months from different socio-economic status (SES) locations in Cape Town against the WHO growth standard.
3. Determine the prevalence of growth abnormalities in this cohort of MA infants by using the converted age-standardised WHO length, weight, weight-for-length, and head circumference z-scores.
4. Assess the association different maternal and infant determinants of health had on infant growth. This included maternal factors such as socio-demographic and -economic variables, maternal ante- and post-natal health, and infant health and feeding practices.
5. Determine the percentage variance that socio-demographic and -economic factors, that were significantly associated with the age-standardised z-scores, represented. This was determined using linear regression modelling.

To achieve aim 4 above, one of the objectives of this research was to develop a questionnaire to record socio-demographic and economic information for each dyad pair. The inclusion of specific information that needed to be recorded were based on various sources such as the WHO MGRS 2006 inclusion and exclusion criteria (gestational age, feeding practices, pathogen exposure, maternal ante-and post-natal health), the immunisation records from Road-to-Health booklet, SADHS, and variables that contributed to variance in linear growth as reported by previous research in SA.

Fundamentally, this research intended to answer the following questions:

1. Do healthy, full-term MA infants deviate from the WHO standard norm?
2. In which direction (positive or negative) did this deviation, if any, occur?
3. At what age, within the study cohort, did any type of deviation occur?
4. Were the same maternal and/or infant factors, as previously reported by global and local research, associated with healthy, full-term MA infant growth, or were there possibly different factors associated with infant growth in this study cohort?

5. Is it possible to conclude that due to inter-population linear growth differences between the infant cohort of the WHO MGRS 2006 growth standard results and those of the current study's MA cohort based on ecogeographical and socio-political influences of healthy, full-term infants, and the subsequent misdiagnosis of growth malnutrition in South Africa, the increasing South African Mixed Ancestry population's overweight prevalence rates can be explained, in part?

# CHAPTER 2: LITERATURE REVIEW

The first person ever to plot the growth of a child was Count de Montbeillard in the $18^{th}$ century and was based on his son's growth from birth to eighteen years of age (*cited in* Hedström, 1969). Since then, growth charts have become one of the tools used by both government and private health organisations to assess the health of a nation or a population group. The first ever official growth chart developed was by the National Center for Health Statistics in 1977, with the recommendation that regular updates were required to compensate for intergenerational linear growth changes that occurr in infants (Ogden *et al*., 2002; Centers for Disease Control (CDC), 2021). The WHO encouraged the use of these growth charts by health care organisations across the globe to assess health of populations (CDC, 2021). As per the National Center for Health Statistics' recommendations, these charts were amended using data from the National Health and Nutrition Examination Survey to form the 2000 CDC growth charts. The data used for the revised charts stemmed from nutritional anthropometry collected since the 1960's in the United States of America.

## 2.1 GROWTH CHARTS: DEVELOPMENT AND DISCREPANCIES

### 2.1.1 DEVELOPMENT OF WHO INTERNATIONAL CHILD GROWTH STANDARD

In the early 1990's a new hypothesis emerged. It was believed that all healthy children should grow at the same rate, irrespective of genetic influences or the geographic region they resided in, under optimal environmental conditions (De Onis and Yip, 1996; De Onis *et al*., 2004a). This was the rationale behind the creation and development of an international child growth standard based on growth data from six geographically distinct regions (Brazil, Ghana, India, Norway, Oman, and the United States of America) in the world that encompassed many different ancestral genetic contributions ('ethnicity'). Data was collected from dyad pairs (mother-infant/child) that complied with very specific conditions, using standardised anthropometric methodology. Those included were full-term infants/children reared under optimal living conditions. These optimal conditions included a gestational age of 37 – 42 weeks with a minimum of 3 – 4 months exclusive breast feeding and continued to approximately 12 months of age in combination with supplementary nutrient-rich food (De Onis *et al*., 2004a; b). In addition, the dyad pair selected lived in a low to very limited disease prone area with adequate sanitation and water source (De Onis *et al*., 2004a; b). Furthermore, mothers selected did not smoke, consumed alcohol, or use drugs ante- and post-natal, and also had an adequate and nutrient-rich diet ante- and post-natal (De Onis *et al*., 2004a; b). Longitudinal (birth to 24 months) and cross-sectional (24 – 59 months) data were collected between 1997 and 2003 by the WHO Multicenter Growth Reference Study (MGRS). The final product was published by De Onis *et al*. in 2006.

The WHO MGRS's rationale was that the inclusion of children from the six major regions of the world would represent a range of genetic input and causal mechanisms, and thus, they could determine globally whether or not children's growth followed the same growth trajectory under optimal environmental conditions, irrespective of genetic influences. Hence, this growth standard could be used anywhere in the world whether in a developed region or in a developing region (De Onis *et al*., 2004a). Yet, as with most research, there are limitations and biases. A limitation of the WHO MGRS study was that many countries were excluded due to the strict inclusion criteria. One such criterion was that children who participated in the study must be predominantly breastfed in the first 12 months after birth. This criterion was based on the fact that the National Center for Health Statistics' and CDC's data were mainly based on formula fed children, and at conception of the new WHO standards it was believed that exclusive breastfeeding for a particular period of time was more beneficial to infants (greater immunisation development) than commercial formula milk products (Campbell and Jones, 1996). Studies showed that infants who were mainly breastfed in the first year of their life had unparalleled healthy growth and development as breast milk provided the correct ratio of vitamins, minerals and energy for optimal growth and development (World Health Organization, 2018). In addition, Tanner and Finn-Stevenson (2002) reported that breastmilk was essential in enhanced sensory and cognitive development while providing pathogenic protection to the infant. A second inclusion criterion was that mothers in the selected dyad pair should have continuous access to nutrient-rich foods. If mothers did not have the means to purchase such foods, it was provided by the WHO research team as part of the participation benefits. Unfortunately, in low- and middle-income countries (LMICs) such conditions are not the norm due to financial constraints that do not always allow daily access to nutrient-rich foods (McCoy *et al*., 2016; Ghattas *et al*., 2019; Li *et al*., 2020). A third criterion was ideally that children were from low to very limited disease prone areas. Africa has one of the highest prevalence rates of tuberculosis (TB), cholera, malaria, and HIV/AIDS in the world (De-Graft Aikins *et al*., 2010). Based on only these three exclusion criteria, many countries were excluded from the WHO MGRS, which solicits the question: 'How 'ethnically' inclusive was the data they used?' There would have been many more regions, if not countries, that may have qualified to partake in the MGRS based on these criteria, even if it was just a small proportion of a population group. Including even small proportions of population groups with diverse ancestral backgrounds from more regions/countries as part of the study's data, might have resulted in a different growth trajectory than the final product that was published.

### 2.1.2 DISCREPANCIES WITH WHO CHILD GROWTH STANDARDS

Worldwide, many countries currently use the WHO MGRS 2006 growth standard as some do not have the necessary resources (money, time, trained personnel), especially LMICs, to undertake such massive longitudinal research projects to establish their own set of national growth references. Projects on such a massive scale are more likely to be undertaken by developed nations such as the United States of America or the United Kingdom. It might have been theorised that the WHO's international growth standard was meant to be used as a guide when nothing else was available. In 2006 in the United States of America, different government organisations convened and decided to use the WHO growth charts only for infants 0 – 2 years as it was a better growth representation of infants in this age cohort than the CDC 2000 charts, but to use the CDC 2000 charts for those 2 – 19 years (Grummer-Strawn *et al*., 2010). In 2007, a joint sitting of the Scientific Advisory Committee on Nutrition and The Royal College of Paediatrics and Child Health in the United Kingdom (Joint SACN/RCPCH) decided that the WHO charts would only be used for children aged 0 – 4 years (Joint SACN/RCPCH Expert Group on Growth Standards, 2007). As countries known for their ancestral diversity of people, the United States of America and the United Kingdom relied on research to inform these decisions. Since then, other researchers started to test the applicability of the WHO MGRS growth standards on their own populations or regions.

#### 2.1.2.1 LENGTH-FOR-AGE DISCREPANCIES

Growth abnormality in length at a particular age (length-for-age) is defined by WHO as individuals that have an age-standardised z-score of more than two (2) standard deviations (SD) below (stunted) or above (very tall) the international growth median ('0') or norm. Since the induction of the WHO MGRS growth standard, researchers noted that there were inconsistencies between the WHO standard and specific national growth references, that may have led to inaccurate prevalence rates in certain countries.

Natale and Rajagopalan (2013) noted that European countries such as the Netherlands and Finland had mean length-for-age means above +0.5 SD, that may lead to overestimation of tallness, whereas Indian and Saudi Arabian children had mean values below -0.5 SD. Similar to the latter, they found that Japanese breastfed children also tended below -0.5 SD from the WHO standard norm, and this was corroborated by Inokuchi *et al*. (2018). The latter researchers found that the WHO standard overestimated stunting in Japanese children. Reddy *et al*. (2020) similarly corroborated the Natale and Rajagopalan's systematic review when they found that the WHO standard overestimated stunting in healthy Indian children who were reared under optimal conditions. Reddy and colleagues found that majority of their healthy Indian children cohort, aged 0 – 24 months had age-standardised length-for-age z-scores between -1 SD and -2 SD. Furthermore, countries such as Thailand also found that stunting prevalence rates were overestimated using the WHO standard, and it was better to use the national reference (Hong *et al*., 2016).

Christesen *et al*. (2016) corroborated the findings of Natale and Rajagopalan (2013) when they found that there was a significant difference between the age-standardised length-for-age results based on the WHO standard and the appropriate national references. Their research showed that the WHO standard underestimated short stature, not stunted per se, as the median or norm of WHO was lower than that of the specific national references used for seven (7) of the nine (9) countries that were tested. The United Kingdom were one of the two countries Christesen *et al*. (2016) found that were on par with the WHO standard, strengthening the decision made by the Joint SACN/RCPCH in 2007 to use the WHO standard for infants 0 – 24 months, but to use the United Kingdom 1990 growth references for children 2 – 18 years (Joint SACN/RCPCH Expert Group on Growth Standards, 2007).

#### 2.1.2.2 WEIGHT-FOR-AGE DISCREPANCIES

Length is a function, in part, of weight, and therefore, if length (or height in those older than 2 years) is lower than the WHO standard norm, weight most likely will be lower as well. This may lead to incorrect diagnosis of an infant's nutritional status based on WHO's age-standardised weight-for-age z-score.

Underweight is defined by WHO as -2 SD below the median (0) or norm. As with length, Natale and Rajagopalan (2013) reported that there was greater variation in weight from the WHO standard norm than in length based on the data they obtained from the publications they reviewed. They found that even in highly developed countries such as Iceland and Japan, deviation direction (positive versus negative) from the WHO standard norm was different. Iceland was above (positive) the WHO standard norm whereas Japan was below (negative) the norm. As previously mentioned for length, Inokuchi *et al*. (2018) also verified that underweight was overestimated in Japanese children. Similarly, Reddy *et al*. (2020) found that nearly one in four healthy Indian infants were diagnosed as underweight using the WHO standard norm and their infant cohort had an overall underweight prevalence of 24.08%. Li *et al*. (2020) presented an underweight prevalence of 27.5% in LMICs based on the WHO standard norm significantly associated with maternal height. Countries in their systematic review included India, Nepal, Ghana, Peru and many other south Asian and sub-Saharan countries though South Africa was not part of the 35 countries they had information from. It may be possible that the underweight prevalence could be lower than reported if there is an overall negative deviation from the WHO standard norm in these countries as shown by Fenn and Penny (2008) and Reddy *et al*. (2020).

Zhang *et al*. (2017) found that healthy Chinese children were taller, and thus, weighed more than what was the WHO standard norm, and hence, overweight prevalence rates would have been higher according to the WHO standard. Khadilkar *et al*. (2010) noted that affluent Indian infants were less likely to be diagnosed as overweight using the WHO standard due to shorter stature. Conversely, Hong *et al*. (2016) noted that Thai infants were more likely to be diagnosed as underweight using the national growth reference than the WHO standard that may imply that using the national reference could underestimate overweight prevalence rates.

#### 2.1.2.3 WEIGHT-FOR-LENGTH-AGE DISCREPANCIES

Weight-for-length-for-age age-standardised z-scores are used to identify wasting (≤ -2 SD below WHO standard norm), overweight (between +2 and +3 SD above WHO standard norm), and obesity (> +3 SD above WHO standard norm). If a national length-for-age reference is below the WHO standard norm, the weight-for-age reference for that country or region may also be below the WHO standard norm, and in turn, may lead to an underestimation of overweight prevalence. This was found by Hong *et al*. (2016) in Thai infants and Inokuchi *et al*. (2018) in Japanese infants.

On the other hand, Tian *et al*. (2019) found that in taller Chinese infants, wasting was underestimated. This would also be true for some European countries where the national length-for-age mean values were above the WHO standard norm such as the Netherlands and Finland, or weight-for-age mean values above the WHO standard norm such as Iceland, according to Natale and Rajagopalan (2013). Hence, underreporting of wasting in these developed nations.

2.1.2.4 HEAD CIRCUMFERENCE-FOR-AGE DISCREPANCIES

Head circumference growth abnormalities include microcephaly (below -2 SD from WHO standard norm) and macrocephaly (above +2 SD from WHO standard norm). Natale and Rajagopalan (2013) concluded that the WHO standard norm for age-standardised head circumference may have been lower than national references. They noted that there was even greater variation in head circumference means than with length and weight. According to them Europeans had the greatest variation from the WHO standard norm, followed by Asian Indians, Australian aborigines, Canadian Cree, and Japanese infants (Natale and Rajagopalan, 2013).

Nicolaou *et al*. (2020) assessed the association between cranial (head) circumference and cognitive function, gross motor skills and language. They presented their height-for-age z-scores results as part of the publication that enabled comparison. Data representing India, Vellore, Bangladesh and Dhaka indicated a high prevalence of microcephaly in these countries which corroborate the findings by Natale and Rajagopalan (2013). Similarly, Reddy *et al*. (2020) also found higher prevalence rates of microcephaly using the WHO standard compared to the national reference.

Bergerat *et al*. (2021) developed new head circumference charts for French infants as they found that both the previous French national reference and the WHO standard were not appropriate any longer due to secular trends. This reinforces the sentiment that growth charts or models must be periodically updated of the researchers at the National Center for Health Statistics in 1977 who developed the first official growth chart (Ogden *et al*., 2002; Centers for Disease Control (CDC)).

2.1.2.5 CONSEQUENTIAL EFFECTS DUE TO DISCREPANCIES

Combined, global research illustrated that whether infants were healthy or from affluent living environments, developed or developing countries, there was a greater possibility of incorrectly classifying them with a growth abnormality if an inappropriate growth model/chart was used. A growth standard indicates how the child should grow whereas a growth reference is population-specific and indicates how children do grow under specific population conditions. It is therefore important that countries collect baseline anthropometric data of healthy, full-term infants living under optimal living conditions to understand which growth model, *i.e*. growth standard or growth references, is most appropriate at specific ages to address which growth model is best as was done in the United Kingdom and the United States of America. In addition, researchers observed that misdiagnosis of nutritional status in infants/children who did not ‘conform’ to the WHO growth standard norm may result in subsequent treatment that lead to even greater health complications later in life (Natale and Rajagapolan, 2014; Singhal, 2017).

It was recognised that while the prevention of stunting and the promotion of linear growth in SGA, LBW or pre-term children showed to be beneficial for neurodevelopmental and other health outcomes, the optimal pattern of infant weight gain was likely to differ in different populations (Blake *et al*., 2016; Singhal, 2017). Furthermore, rapid weight gain and post-natal growth acceleration in healthy, full-term infants in LMICs was associated with a greater risk for obesity and non-communicable diseases (NCDs) later in life (Cameron and Demerath, 2002; Singhal 2017). This in turn would lead to greater financial strain on government subsidised medical facilities. Therefore, the combined use of the WHO MGRS growth standard and a standardised population-specific growth reference, as is done in the United States of America and the United Kingdom (Joint SACN/RCPCH Expert Group on Growth Standards, 2007; Grummer-Strawn *et al*., 2010), may better inform health care policy development and regulate future preventative health care for population groups at risk (Christesen *et al*., 2016).

It is therefore important to collect baseline data on healthy, full-term infants in order to assess whether the WHO growth standard norm is appropriate in a specific country or region, or if a national growth reference would be best suited. In addition, it is also important to understand which socio-demographic and/or socio-economic factors, other than genetic phenotypic expression, may have influence any type of deviation, if any, from the WHO standard norm or a previous national reference such as intergenerational effect and/or secular trends. Knowledge of how various internal (within human body) and external (in the environment) factors affect linear growth is therefore relevant to inform why deviations may occur in different populations.

## 2.2 FACTORS AFFECTING LINEAR GROWTH

Human growth is influenced by various interrelated factors (Bogin, 2012) such as genetics (Moore *et al*., 1982; Hirt *et al*., 1987; Bogin, 1999; Weedon and Fraylin, 2008) and the living environment (Cowgill *et al*., 2012; Wells, 2012). Fusco and Minelli (2010) explained phenotypic plasticity in development of multicellular organisms due to environmental stressors that may lead to alterations of developmental growth trajectories. Environmental factors may include nutrition (Steckel, 2008; Stulp and Barrett, 2016) and hygiene and/or exposure to disease (Walker, 1995; Labadarios and Steyn, 2005; Akachi and Canning, 2007). If an individual's growth does not follow a 'normal' population growth trajectory, it may be due to environmental and/or genetic factors. These factors are discussed below.

### 2.2.1 GENETIC VARIATION AND INTERGENERATIONAL EFFECTS ON LINEAR GROWTH

Children's DNA is a representation of 'ancestral' genetic influences (Stinson, 2009). Genetic influences incorporate the genes from both parents and the causal mechanisms that influenced biological growth resulting in the expression of certain phenotypic traits such as height/stature (Jee *et al*., 2018). These causal mechanisms include sexual selection, gene flow, genetic drift, intergenerational effects, and micro-evolutionary adaptations (Katzmarzyk and Leonard, 1998; Pfeiffer and Sealy, 2006; Fusco and Minelli, 2010).

Maternal height can be considered as an intergenerational effect, *i.e*. a phenotypic expression of the genotype to environmental changes or stressors (Fusco and Minelli, 2010; Martorell and Zongrone, 2012), and has previously been significantly associated with gestational age, birth length and weight (Zhang *et al*., 2015; Budree *et al*., 2017). If the parents' phenotypic expression is that of short stature, so too will be the infant's stature at birth even if the infant was healthy (Rani *et al*., 2021). For example, within the same topographic region, like sub-Saharan Africa, the Maasai (Kenya and Tanzania) are amongst the tallest people in the world whereas the African Pygmies (Cameroon, Gabon, Central Africa Republic, Democratic Republic of Congo, southern Rwanda and Nigeria) are the shortest (Galvin *et al*., 2004; Jarvis *et al*., 2012; Patin *et al*., 2009; Galvin *et al*., 2015). The difference in body size between these two groups is most likely due to the amount of UV exposure (O'dea, 1994), *i.e*. phenotypic plasticity. Therefore, both groups have improved their chance of survival in their unique ecogeographical habitat through micro-evolutionary adaptations of a phenotypic expression of a genotype (Dickens and Rahman, 2012). Many research studies have shown inter-populational variation in adult height (stature) (Rühli *et al*., 2008; Gustafsson and Lindenfors, 2009; Ross and Manneschi, 2011; Albanese *et al*., 2016; Spake and Cardosa, 2018). If different nations have significant variation in height, it stands to reason that a similar difference will be observed in the children of those population or 'ethnic' groups. Thus, the use of one growth standard for all does not seem scientifically reasonable.

Thermoregulation is another micro-evolutionary causal mechanism (Lomolino *et al*., 2006) affecting body shape according to ecogeographical patterns. In warmer climates mammals, including humans, have adapted a more linear shape to increase the surface area to volume ratio enabling greater heat dissipation compared to those in colder climates where the surface area has been reduced and volume of the thorax increased to assist in heat retention, *i.e*. Bergmann's rule (*cited in* Wells *et al*., 2012). Mammals also tend to have longer extremities in warmer climates than those in colder climates, *i.e.* Allen's rule (*cited in* Wells *et al*., 2012). Jantz and Meadows Jantz (2017) noted that phenotypic plasticity of body extremities in a contemporary society has led to secular changes over the last two centuries, reinforcing the previous statement of regular updates to growth trajectory charts and accurately estimating children's height.

Both these phenotypic adaptations have been extensively studied in humans by Katzmarzyk and Leonard (1998), Wells (2012), and many others. To understand why children grow differently it would be best to understand the environmental changes or stressors that causes expression of the phenotypes linked to the genotypes. Consequently, identifying the environmental stressors that causes children to grow differently, may help future implementation of government policy and public awareness, helping future generations to achieve growth trajectories that are optimal as advocated by WHO.

### 2.2.2 SOCIAL DETERMINANTS OF HEALTH AFFECTS LINEAR GROWTH

So, irrespective of the genetic height potential of any person, environmental (living) conditions play a crucial role in growth and adult height attained (Martorell and Zongrone, (2012). During adverse living conditions, body 'maintenance' is more important in lieu of growth (Walker *et al*., 2006). This means that the body's primary functions and existing muscle, organs and bone tissue must be maintained with whatever nutrients are absorbed, and therefore, growth of skeletal tissue is non-essential. The WHO concluded that children's growth rate and development are more likely to be affected by nutrition, feeding methods, living conditions and healthcare rather than genetics (International Pediatric Association, 2006). This view is strengthened by Martorell and Zongrone's (2012) discussion of intergenerational effects such as maternal undernutrition in childhood and during pregnancy. Maternal undernutrition during childhood would cause the mother not to reach her full height potential (so she's smaller in size), consequently restricting intrauterine fetal growth. Maternal undernutrition during pregnancy would limit nutrient-availability for fetal growth, again causing growth faltering.

Combined, these two aspects of maternal undernutrition will cause intergenerational growth faltering. Hence, if living conditions are inadequate such as nutrient-rich food availability, mothers nor their offspring can reach their full height potential (Donald *et al*., 2018).

Steckel (1995; 2008) concluded that linear growth was a result of access to nutrient-rich food offset by the body's metabolic requirements such as physical activity and chronic illnesses or disease. In infants, 'output' would include growth of various tissues, including cellular multiplication and divergence of chondrocytes in skeletal tissue (Jee *et al*., 2018). Since the 1900's, contemporary medicine has determined that in a nutrient-deficient, disease prone, and/or high metabolic output environment, the infancy-childhood transitional age (age 24 months) is deferred, preventing an increased amount of the growth hormone insulin-like growth factor 1 to be released, and may possibly result in linear growth faltering (Hochberg, 2009; Gawlik *et al*., 2011; Hochberg, 2011; Perera and Herbstman, 2011; German *et al*., 2015). First demonstrated in 1957, this growth stimulating hormone triggers activity of osteoblasts and chondrocytes to promote growth (Bogin, 1999). Hence, in the event of malnutrition, disease and other adverse socio-economic conditions, the infant-childhood transitional age is deferred when nutrient input is primarily directed to body 'maintenance' in lieu of growth (Hochberg, 2009).

Micronutrient deficiencies, such as iron, iodine and/or vitamin A deficiencies, were reported to affect growth in infants and children (SAVACG, 1996; Oelofse *et al*., 2002; Faber, 2007; Black *et al*., 2013; Rothman *et al*., 2018; Senekal *et al*., 2019; Li *et al*., 2020; Nicolaou *et al*., 2020; Masuke *et al*., 2021). Faber (2007) noted that iron deficiency was more prevalent in females which would have had a knock-on effect during foetal development, resulting in a greater prevalence of stunting in the offspring. Protein-energy malnutrition was more prevalent in South African rural areas than urban areas which might have increased stunting prevalence (SAVACG, 1996; Zere and McIntyre, 2003; Sartorius *et al*., 2020). It has been shown that although urbanisation has increased in LMICs, power of purchase does not automatically improve to such an extent that allows purchase of nutrient-rich foods, but rather purchase of less expensive foods such as bread, maize products, potatoes, onions, and processed food products (Sartorius *et al*., 2020). Those in rural areas, where land is available unlike urban areas, often grow home vegetable gardens to supplement food purchased.

Feeding practices of infants have also shown to affect growth (Rothman *et al*., 2018; Lessa *et al*., 2019; Masuke *et al*., 2021; Morgen *et al*., 2021). One of the criterions of the WHO

MGRS was that infants should have exclusive breastfeeding for 3 – 4 months and had continued breastmilk until the age of 12 months, if not longer (De Onis et al., 2004a). Black *et al*. (2013) and Desmond and Casale (2017) reported that breastfeeding had no effect on infant length and/or weight, while Nicoloau *et al*. (2020) concluded that it was associated with head circumference measurements. What is interesting is that Faber (2007) stated that formula feeding had a protective effect on growth as it lessened iron deficiency. It was explained that infants are born with a natural iron store that depletes by the age of four months, and iron concentrations in breastmilk are lower than in formula milk. Hence, the introduction of formula milk helps restore the infant's iron concentration, aiding growth. On the other hand, early introduction of complementary foods can lead to a greater risk of infants who are overweight or obese within the first year of life (Morgen *et al*., 2021), and it may also cause early cessation of breastfeeding (Lessa *et al*., 2020). Masuke *et al*. (2021) noted that early introduction of complementary food with a limited dietary variety lead to greater risk of infants being underweight and wasted.

With such intricate factors affecting children's growth, and the vast body of research available, it was interesting to note that in many of these studies maternal education was significantly associated with different parameters of growth (Black *et al*., 2013; Desmond and Casale, 2017; Sartorius *et al*., 2020). Masuke *et al*. (2021) mentioned that mothers without proper primary healthcare knowledge were more likely to supplement breast milk with solids earlier than recommended. Apart from infant 'best practice' knowledge, higher levels of education allow for better, and more, opportunities to earn a higher level of income. In turn, a high-income level allows greater financial independence regarding residential location, greater dietary variety, access to in-house sanitation and water sources, and quick access to medical professionals. Another aspect of better financial resources in the 21st century is access to online information via digital devices linked to Wi-Fi (wireless fidelity). Easy access to the world wide web (www.), permits readily available information regarding healthy child development (linear growth, motor skills development goals and cognitive development) to many mothers.

## 2.3 SOUTH AFRICA'S DIVERSE POPULATION AND THEIR MALNUTRITION PREVALENCE

Differences in ancestral genetic input and intergenerational causal mechanisms that influence phenotypic expression of the genotype, in combination with unique socio-political and socio-economic conditions, have created a unique diversity of population groups in South Africa (Petersen *et al*., 2013; Busby *et al*., 2016; Montinaro *et al*., 2017). Such unique individuals may, therefore, differ in terms of their growth rates and development patterns when compared to the WHO MGRS child growth standards.

### 2.3.1 SOUTH AFRICA'S DIVERSE POPULATION

South African individuals of African descent (AD) make up the largest percent (80.9%) of the national population with mixed ancestry (MA) individuals the second largest (8.8%) and European descent (ED) the third largest group (7.8%) (Statistics South Africa, 2021). The fourth official group as reported by Statistics South Africa is the Indian/Asian group at 2.6%. Figure 2.1 represent the population group distribution in SA based on data from Census 2011 (Statistics South Africa, 2012).

Contemporary individuals of AD (also referred to as Black South Africans) are the descendants of agro-pastoral Bantu-speaking African people who journeyed from West and Central Africa to southern Africa (Petersen *et al*., 2013, Arendse, 2018). Genetic research reported that during their journey south at around 1 500 years ago, admixture occurred with people from the Niger Basin, East Africa, the northern Congolese Pygmies and finally the Khoe-San in Southern Africa (Montinaro *et al*., 2017). Several different ancestral clans exist in SA and the surrounding countries with each clan showing evidence of different percentage genetic contribution from these four main groups depending on their geographic location. In South Africa, African descendent clans include the AmaXhosa, AmaZulu, AmaNdebele, Basotho and all other clans as AD (Arendse, 2018). The AmaXhosa are mainly found in the Eastern Cape province (EC), the AmaZulu mainly in KwaZulu-Natal province (KZN), while the AmaNdebele and Basotho are both mainly found in the northeast provinces of SA (Limpopo and Mpumalanga provinces). The Gauteng province (GP) can be described as the financial hub of SA, and therefore, many individuals from these and other clans have migrated to this region to seek better work opportunities.

The second largest population group in SA consist of individuals with the highest global intra-populational heterozygosity (Petersen *et al*., 2013; Montinaro *et al*., 2017; Arendse, 2018). These individuals were termed 'Coloured' by the South African apartheid government and Statistics South Africa still uses the term to identify them. This term was implemented because the apartheid regime was unsure what to name them as they were neither from AD nor ED (Petrus and Isaacs-Martin, 2012; Statistics South Africa, 2016). More than 90% of South Africa's contemporary MA individuals self-identify as 'Coloured' (Statistics South Africa, 2021). The term 'mixed ancestry' incorporates more recent ancestral genetic admixture than that of individual of AD, *circa* 360 years ago (Petrus and Isaacs-Martin, 2012; Inwood and Masakure, 2013; Montinaro *et al*., 2017). It is believed that in certain areas in SA communities of homogenous Khoe-San individuals reside, but due to the apartheid regime's 'racial' classification system these individuals' antecedents were grouped within the broader 'Coloured' population group (Tawha *et al*., 2020). In addition to the Khoe-San and African non-Khoe-San genetic input, as with AD, these individuals mainly contain ancestral genetic input from the United Kingdom, France, Germany, the Netherlands, India, Indonesia, and Han-China to name (Petersen *et al*., 2013; Montinaro *et al*., 2017; Arendse, 2018). As with individuals of AD individuals, MA individuals' ancestral genetic input is geographically distinctive where for example individuals of MA from Cape Town, Western Cape Province (WC), have a more Asian genetic input than individuals in the Eastern Cape Province (EC). The Cape Townian MA individuals though have less Khoe-San genetic input than their Northern Cape Province (NC) counterparts (Petersen *et al*., 2013). Individuals of MA in the EC have the greatest African non-Khoe-San ancestral genetic input than either those in the Western or Northern Cape Provinces and the least contribution from their Asian ancestors (Petersen *et al*., 2013). Petersen *et al*. (2013: e1003309: 12) described South African MA individuals as people with "...the largest within population and regional-associated variability" with regard to genetic heterozygosity.

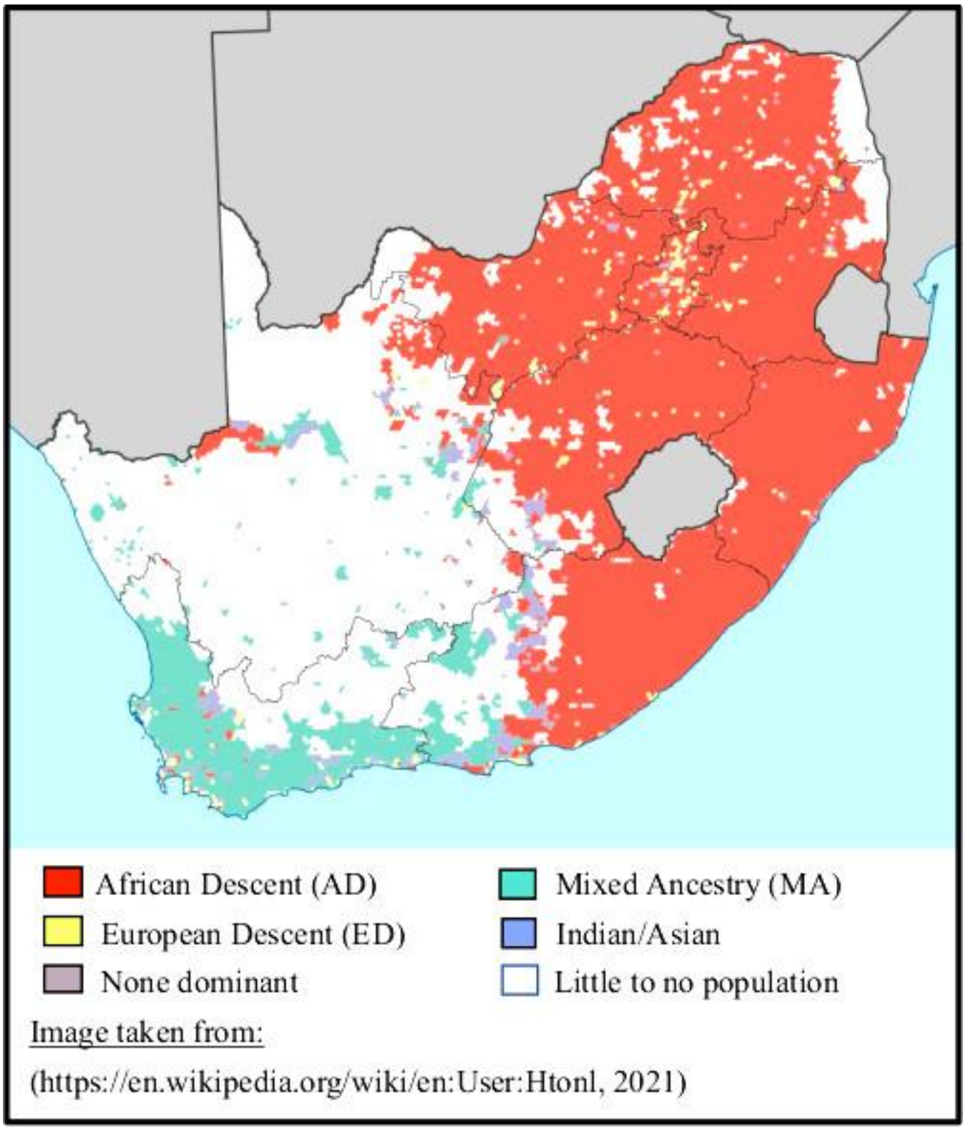



**Figure 2.1: Map of South Africa, illustrating the distribution of AD, MA, and EA individuals. This map was taken from http://www.google.com's South Africa 2011 dominant population group map.**

Individuals of ED is the third largest population group who historically stemmed from colonialism. Their arrival started with the initial influx of Dutch sailors when a Dutch company called the '*Vereenigde Oost-Indische Compagnie* or *VOC*' had to create a 'new' settlement at the Cape Colony at the southern tip of Africa, *circa* 365 years ago, to restock food and fresh drinking water at the southern point of Africa between Europe and the Middle. A further influx of colonial settlers continued later with the French, British and Germans. Ecogeographic changes and restricted admixture with more established local population groups such as the

Khoe-San and non-Khoe-San African descendants in SA created the most genetically homogenous South African population group (Petersen *et al*., 2013) though they are anthropometrically different from their ancestors (L'Abbé *et al*., 2013; Liebenberg *et al*., 2015).

The fourth largest group in SA consist of Indian/Asian, while the remaining individuals are termed 'Other' by the South African government (Statistics South Africa, 2021).

These are the three main population groups in SA, and account for 97.5% of the total South African population. With such varied ancestral backgrounds, and intergenerational effects due to historical socio-political and socio-economic inequalities, the relevant question would be: Do all South African children grow the same?

### 2.3.2 APPLICATION OF THE WHO GROWTH STANDARD IN SOUTH AFRICA

SA currently uses the WHO child growth standards for length, weight, weight-for-length, and head circumference which were implemented in 2011 in the new Road-to-Health booklet issued by the government at all health care facilities, to mothers upon the birth of their infants. A technical report in 2006 by WHO reported a 40% stunting prevalence in South African children under 5 years (De Onis *et al*., 2006). The latest SA Demographic and Heath Survey (SADHS) reported that 1 in 3 boys, and 1 in 4 girls, are stunted in this age category (National Department of Health *et al*., 2017). Sanders and Reynolds (2017) calculated that an estimated 1.5 million (27.4%) South African children younger than five years were stunted. The SADHS also reported that 24% and 13% of children younger than 5 years in the middle and top wealth quintiles, respectively, were estimated as stunted according to the WHO MGRS growth charts (National Department of Health *et al*., 2017). Incorrect diagnosis of stunting may lead to overfeeding by mothers as a maternal instinct to increase feeding so the child can grow faster, possibly increasing the risk of overweight/obesity. Infants who become overweight or obese in the early phases of growth, may increase their risk of adult-onset NCDs. The SADHS reported that children under 5, classified as overweight, were double the international average (6.1%). The high prevalence rate of stunting and overweight/obesity in SA has been labelled the "double burden of malnutrition" (Steyn *et al*., 2005; Norris *et al*., 2014; Senekal *et al*., 2019).

It would be a natural response for a mother in the middle to upper wealth quintiles to increase nutrition if her child is diagnosed as stunted, and hence, inadvertently cause an increased weight-to-height ratio that may subsequently lead to a greater risk of overweight/obesity. In turn, early infant overweight or obesity may lead to increased risk of non-communicable diseases such as type 2 diabetes and hypertension in adults. For this reason, it is vital to consider the different genetic input and socio-economic conditions of AD and MA children that influence their growth rates.

Numerous South African research focused on national prevalence rates, irrespective of population classification, whereas some specifically focused on AD and/or MA. Those studies included all children, whether they suffered from chronic illness or were diagnosed with a disease. Few reported the number of children that were HIV positive or exposed (Budree *et al*., 2017; Barnett *et al*., 2021), but uninfected (Morden *et al*., 2016). Those who specified the percentage, included these children nonetheless. It is also seldom that South African nutritional anthropometric research, whether longitudinal or cross-sectional, have similar exclusion criteria as the WHO MGRS or that they separate the different population groups.

### 2.3.3 SOUTH AFRICA'S MALNUTRITION PREVALENCE RATES

#### 2.3.3.1 STUNTING

In a cross-sectional study, Oelofse *et al.* (2002) estimated a prevalence rate of 18.0% for MA and 7.0% for AD infants aged 6 – 12 months in a region within 60 km from one of the research locations this study intended to sample in the WC. Faber (2007) had similar stunting prevalence (9.0%) as the previous researchers for AD infants of the same age range in KZN, and their cohort was five times greater. In a later study, Faber and colleagues (2015) sampled four provinces in SA (WC, KZN, LP, and Northern Cape province (NC)). Their mean age was 3.6 years and the lowest prevalence was in WC (unspecified population groups) at 13.9% with the highest in NC at 40.9%. Said-Mohamed *et al*.'s (2015) systematic review used data prior to 2009 (1994, 2003, 2008), but they only reported stunting prevalence in WC and NC at 35.0% and 37.0%, respectively. Du Plessis *et al*. (2016) also conducted research within 110 km from the present study's research location in the Western Cape region and recorded a prevalence of 28.8% for their infant cohort younger than 24 months. They had a mix cohort of MA and AD, but they did specify if the majority of infants were MA. Budree *et al*.'s (2017) research was conducted in a peri-urban community within 45 km from one of this study's research locations, and they estimated stunting prevalence at 2 months, 6 months and 12 months based on longitudinal data. MA infants had a stunting prevalence of 22.0%, 16.0% and 17.0%, respectively, at the various ages, and AD infants had 12.0%, 10.0% and 17.0%, respectively. Desmond and Casale (2017) reported a 19.3% prevalence based on longitudinal data from 1990 – ongoing for 2-year-olds in GP, but no population was specified. Senekal *et al*. (2019) had prevalence rates of 21.4% and 20.4% for infants aged 1 – 5 years in WC and GP urban areas, respectively. Le Roux et al. (2020) conducted research in NC, and estimated prevalence rates of 8.7% - 13.6% and 5.8% - 4.7% for boys and girls, respectively, from birth to 6 weeks of age. Though Barnett *et al*. (2021) calculated the mean length-for-age at-1.16 SD for their infant cohort at age 24 months, they did not report a prevalence rate.

2.3.3.2 UNDERWEIGHT AND WASTING

A child is classified as underweight when they have a weight-for-age z-score of -2 SD below the WHO growth standard norm of zero, whereas a child classified as wasted has a weight-for-length-for-age z-score -2 SD below the WHO growth standard norm. Underweight and wasting prevalence rates were much lower than the stunting prevalence. Underweight prevalence rates were less than half to a third of the reported stunted prevalence for both Oelofse *et al*. (2002) and Faber (2007). Neither had infants categorised as wasted. Du Plessis *et al*. (2016) had an underweight prevalence less than 5.0% and wasting at less than 1.0%. Budree *et al*.'s (2017) cohort had half the prevalence rates for stunting amongst the MA infants (12.0%, 8.0%, 9.0%) at the various ages as stated previously, whereas AD infants had a greater wasting prevalence (5.0%) at 6 months than underweight prevalence (3.0%). The underweight and wasting prevalence were the same at 2 months (6.0%) and 12 months (2.0%) for AD, which at these ages were half or less than MA. Senekal *et al*. (2019) had underweight prevalence rates below 6.0% in both WC and GP urban areas, and 1.0% or less for wasting. Le Roux *et al*.'s (2020) research results for underweight and wasting prevalence rates were the highest of all previous studies. Boys were more likely to be underweight at birth (9.4%) than girls (7.4%), and this difference increased significantly at age 6 weeks (11.4% versus 3.3%, respectively) (ref). Yet again, Barnett *et al*. (2021) did not estimate prevalence rates, but recorded a mean weight-for-age of -0.31 SD and a mean weight-for-length-for-age of +0.28 SD.

2.3.3.3 OVERWEIGHT AND OBESITY

Overweight and obesity diagnosis are based on the weight-for-length-for-age z-score, and not on the weight-for-age z-score. A child diagnosed as overweight has a weight-for-length-for-age z-score between +2 SD and +3 SD, and an obese child has a weight-for-length-for-age z-score above +3 SD from the WHO growth standard norm of zero. Oelofse *et al*. (2002) did not record overweight and obesity prevalence rates. Faber (2007) and his colleagues' (2015) research results for overweight and obese prevalence rates were estimated to be greatest in KZN at 30.0% and 14.7%, respectively. The latter study showed WC had the second highest rate at 5.4%, but very low in LP (1.5%) and NC (1.0%). Du Plessis *et al*.'s (2016) prevalence rates were the greatest of all publications that specifically refer to MA and AD for their infant cohort that mainly comprised of MA. Budree *et al*.'s (2017) AD overweight and obesity prevalence rates were more than double that of MA at all ages recorded. Senekal *et al*. (2019) recorded a significantly greater prevalence of overweight in WC (15.7%) than in GP (7.7%), and the obesity prevalence was slightly more in WC (7.1%) than in GP (6.6).

All these SA studies show a general trend in MA and AD infants younger than five years. Stunting prevalence tends to be greater in MA whereas overweight and obesity is more prevalent in AD. Rural areas, especially in KZN and NC, the double burden of malnutrition is greater than in some of the urban area of WC and GP. Though overweight and obesity was more prevalent in AD, MA NCD prevalence rates are greater than AD's. The question begs to be asked: "Why are MA at greater risk of adult-onset NCDs when AD's weight-for-age and weight-for-length-for-age was greater than MA at a critical phase in linear growth?"

As this thesis had a time limitation, it was decided to focus on one population group and only healthy, full-term infants. The reason MA was chosen, was because the PhD candidate originates from this community specifically. Her ancestral heritage includes '*Strandloper*' (indigenous coastal dweller on the south coast of South Africa), descendants from St. Helena Island in the South Atlantic Ocean, German and Malaysian indentured labourers. Currently not much growth data on healthy, full-term MA infants exists for rural or urban areas, as does for AD (Norris *et al*., 2009; Makanjana and Naicker, 2021).

### 2.3.4 FACTORS AFFECTING LINEAR GROWTH AND HEALTH OF SOUTH AFRICANS OF MIXED ANCESTRY

Although most individuals of MA self-identify as 'Coloured', others describe themselves as Cape Malay, '*Kleurling*' ('Coloured' in Afrikaans), '*Bruinmens*' ('Brown person' in Afrikaans), Khoe-San or Bushmen. In some instance people in the Northern Cape province self-identify as 'Baster' who are descendants from admixture between Dutch/German colonialists and Khoe-San at the turn of the 19th century living in and around the Cape Province (Lang, 1998; De Wit *et al*., 2010; Inwood and Masakure, 2013; Petersen *et al*., 2013; Uren *et al*., 2016).

Petersen *et al*. (2013: e1003309: 12) described MA as possibly having "...*the most diverse genomic contributions…"* and "...*the largest* […] *regional-associated variability*" intra-population. They determined that the MA individuals they sampled contained approximately 64.3% Khoe-San (mitochondrial DNA) contribution and generally this contribution decreased moving west to east (Petersen *et al*., 2013). Hence, as stated previously their ancestral lineage is geographic different. Cape Townian MA individuals have more Asian ancestral genetic contributions than individuals from the EC region, and less Khoe-San ancestral input than individuals from the NC region (Petersen *et al*., 2013). MA individuals from the EC region has the greatest African non-Khoe-San ancestral genetic contribution with the least amount of Asian ancestral genetic contribution (Petersen *et al*., 2013; Arendse, 2018).

Khoe-San people were known to be short with males reaching an average adult height of 150 centimeters (cm) (Pfeiffer and Sealy, 2006; Eideh *et al*., 2012). Their linear shape and short stature were micro-evolutionary adaptations to their ecogeographical habitat as they lived on the savanna grasslands to the semi-arid/arid climate of the Karoo, and also due to food availability as they were hunter-gatherers (Rosa and Brehm, 2011; Morris *et al*., 2014; Busby *et al*., 2016; Uren *et al*., 2016). Walker *et al*. (2006) noted that contemporary Khoesan children had a slow growth period in the first ten years of life due to a nutritional adaptation (40% of adult body size by age 10) with a notable adolescent growth spurt. It can be hypothesised that MA individuals with Khoe-San ancestral genetic input would be genetically predisposed to shorter stature (Dickens and Rahman, 2012), and would possibly exhibit a similar growth trajectory compared to other groups of individuals with little to no Khoe-San genes. Even if these children live under optimal living conditions, their growth trajectory would most likely be different to the growth percentiles and growth trajectory prescribed by the WHO MGRS growth charts. If most of their growth occurs during the adolescent phase, the growth charts that are used to assess their growth and development should incorporate this.

In addition to a genetic predisposition to short stature, a large number of MA individuals live in poor socio-economic conditions. From the mid-19$^{th}$ century to its end, socio-political circumstances led to severe socio-economic inequalities between the bureaucratic population groups in South Africa. Consequently, it affected many aspects of MA individuals' living conditions such as quality of education, income prospects, health care accessibility, spatial restriction and legalised marital segregation between the population groups, *i.e*. no admixture (Petrus and Isaacs-Martin, 2012). Of the 40% of South Africans that lived below the lower-bound poverty line of R647 ($41.00 or €36.00) per person per month in 2015, 23% were MA (Statistics South Africa, 2017a).

Protein-energy malnutrition and chronic gastric infections are categorised as a "Group I" cause-of-death by the Global Burden of Diseases (Statistics South Africa, 2017b). Diarrhoea has been shown to be a common medical cause for young children in SA to be admitted to hospital with many of them suffering from malnutrition (Shisana *et al*., 2013; Isaacs-Long *et al*., 2017). According to a discussion document titled 'An Overview of Health and Health Care in South Africa 1994 – 2010: Priorities, Progress and Prospects for New Gains' which was commissioned by the Henry J. Kaiser Family Foundation, maternal and childhood underweight outranked (6th) high blood pressure (8th), diabetes (9th) and high cholesterol (10th) (Harrison, 2009) as cause of death with 12% of all deaths in children younger than five years attributed to malnutrition (Harrison, 2009). Therefore, nutrient-deficient disorders such as vitamin A, folate and iron deficiencies and increased pathogen exposure (HIV, tuberculosis, diarrhoea) in urban areas may invariably affect an individual's height in different phases of linear growth development due to a greater metabolic output (Labadarios and Steyn, 2005; Akachi and Canning, 2007, Faber, 2007; Shisana *et al*., 2013). MA individuals residing in urban areas may have greater accessibility to readily available nutrient-rich food and/or medical facilities, but financial constraints prevent them from purchasing such foods. At present, health inequities or disparities are still commonly found among MA. This is due to social determinants of health which include social, environmental, cultural and physical factors that they are born into, grow up in and function with throughout their lifetimes (Danaher, 2011; Statistics South Africa, 2017b).

### 2.3.5 APPLICABILITY OF WHO GROWTH STANDARDS FOR MA

Thus, in summation, based on differential genetic and environmental influences on individuals of MA's growth, it is probable that their growth trajectory may be inconsistent with the international reference. These factors were discussed for MA individuals in Arendse *et al*. (2022, in print). Furthermore, MA adult stature anthropometric data strengthens the likelihood that children from this population group may be classified as below the 'norm' in terms of height and/or weight at a specific age or development phase according to the WHO MGRS growth charts. Mothers or primary caregivers, of children who are diagnosed with severe malnutrition, *i.e*. stunting or wasting, most probably would be advised to supplement the nutritional intake of the child. Hence, this may result in a greater weight-to-height-for-age (obesity) ratio which may later result in an additional burden of disease (*i.e*. coronary heart diseases, type II diabetes, and hypertension) during the adult phase of the individual (Huxley *et al*., 2000; Cameron and Demerath, 2002). If growth charts are to be used as a general health indicator of a population group, standardisation of population-specific growth models/charts may in turn inform health care policy development and regulate future preventative health care for population groups that are at risk (Christesen *et al*., 2016). Individuals of MA are more likely to be misdiagnosed with a growth disorder using the WHO MGRS growth chart based on recent poverty trends (Statistics South Africa, 2017a), and thus, lead to further financial strain on government subsidised medical facilities already under enormous strain. With the intended roll out of a National Health Insurance Plan (Department of Health, 2017) in SA in the near future, it is imperative to understand the factors at play and the effect they may have on growth of a population group clearly at risk. Such research will help inform policy development and future healthcare practices to lessen the burden of disease for the MA population group.

Therefore, the question asked was whether these MA children should be statistically compared to a set of standards derived from combined population data representing countries that have (1) a different historic genetic input (affected by specific genetic influences such as ecogeographical patterns), and/or, (2) have a different set of environmental (living) conditions affecting growth rate and development patterns than MA children in SA (Vignerová *et al*., 2015; Christesen *et al*., 2016).

As with the WHO MGRS's rationale that states the growth of children under optimal living conditions are the same, irrespective of genetic input, the data collected from the mid-upper socio-economic locations (3$^{rd}$ to 4$^{th}$ wealth quintiles) were to help determine if the growth percentiles of MA children aged 0-18 months corresponded to the international standard. Two locations in the Western Cape province were selected in the research region that represented different socio-economic status (SES) groups. The SES comparative data was to help analyse the association SESs had on growth in order to correctly diagnose malnutrition and/or a growth disorder within this population group. Although this study's cross-sectional data would have only provided a 'snapshot' in time (Institute for Work and Health, 2015), it would have identified if there were discrepancies in the growth trajectory of MA infants compared to the WHO MGRS 2006 child growth standard.

## 2.4 RESEARCH OBJECTIVES

The research objectives for the current study are to:

1. Collect baseline data for healthy, full-term MA infants aged 0 – 18 months that can be used by various people in different spheres of public health.
2. Determine if a significant number of children who are reared with little to no hindrance for optimal growth, fell below -2SD from the WHO standard norm with regard to the age-adjusted z-scores for length-for-age, weight-for-age, weight-for-length-for-age and head circumference-for-age.
3. Determine the prevalence of growth abnormalities in a healthy MA infant cohort.
4. Determine if there were significant differences between the SES groups related to maternal socio-demographic and socio-economic factors, and infant health factors.
5. Determine if these socio-demographic and socio-economic factors significantly influenced the age-adjusted anthropometric parameters.
6. Determine the percentage variation contribution of each significant maternal and/or infant factor using multivariate linear regression analysis.

# CHAPTER 3: PARTICIPANTS & METHODOLOGY

## 3.1 PARTICIPANTS

This research aimed to target three age cohorts: (i) 0 – 5.9 months of age, (ii) 6 – 11.9 months of age and (iii) 12 – 18 months of age, with equal distribution between males and females. Questionnaire data from MA dyad pairs were combined with the child anthropometric data to better understand the impact socio-economic status (SES) backgrounds, medical and early childhood environmental factors may have on the growth trajectory of the infants.

Data were collected from August 2019 to March 2020 at three research locations: Bishop Lavis Clinic, Diep River Clinic and MeloMed Tokai Private Hospital, all located in the Western Cape Province, SA (Figure 3.1). Ethical approval for the research study was obtained from the University of Cape Town's Human Research Ethics Committee (HREC Reference: 075/2019; Figure C.1, Appendix C). Ethical approval to visually record anthropometric methodology procedures did not form part of the ethics approval application to the Ethics Committee. Permission to conduct research at Bishop Lavis Clinic was obtained from the Health Impact Assessment, Health Research sub-directorate in the Western Cape Province (Reference: WC_201905_037; Figure C.2, Appendix C) through the National Health Research Database of SA whereas permission to conduct research at Diep River Clinic was obtained from City Health, City of Cape Town (Reference: 24486; Figure C.3, Appendix C). Permission to recruit participants at MeloMed Tokai Private Hospital was obtained from the paediatric doctor, Dr. Shukri Raban, whose surgery was utilised for data collection.

### 3.1.1 BISHOP LAVIS CLINIC

Bishop Lavis Clinic is a government community health centre (CHC) where very few of the clientèle have private health insurance (private care medical schemes). Government health care centres provide services for all age groups that include infant health care, consultations and medication for common or chronic illnesses, human immunodeficiency virus (HIV)/acquired immunodeficiency syndrome (AIDS) testing and counselling, antiretroviral therapy dispensing, and tuberculosis screening, medication and follow-up consultations. Larger public healthcare facilities, such as Bishop Lavis Clinic, may also have a pharmacy for monthly chronic medication dispensing, a trauma ward, dentistry, and psychological counselling and treatment. Primary health care clientèle who do have private care medical schemes attend the government health care clinic for general paediatric check-ups such as immunisations, non-severe coughs, common colds, non-severe dermatological issues *etc*. (personal communication with clientèle at Bishop Lavis Clinic).


<u>Sources:</u>

1. Global position of South Africa (SA):
   https://geology.com/world/south-africa-satellite-image.shtml (accessed 03 August 2020)
2. Western Cape Province (WC), SA:
   https://en.wikipedia.org/wiki/Western_Cape#/media/File:Western_Cape_in_South_Africa.svg (accessed 03 August 2020)
3. City of Cape Town, WC, SA
   https://en.wikipedia.org/wiki/City_of_Cape_Town (accessed 03 August 2020)
4. Suburb map of City of Cape Town:
   https://www.portfoliocollection.com/map/western-cape-peninsula (accessed 04 August 2020)

**Figure 3.1: Map of research locations in the City of Cape Town, Western Cape Province, South Africa.**
**Each red star ( ) on the map of the "Suburb map of City of Cape Town" indicates the locations of the research sites in the Cape Town Metropole. The map was compiled and created by the PhD candidate.**

The CHC is in the suburb of Bishop Lavis; approximately 3 kilometres north from Cape Town International Airport; that was established in 1951 as a Group Area Act (Group Area Act of 1950) relocation site for people who were considered non-European. The suburb has an area of 2.58 square kilometres (km$^2$) with a population density of approximately 10 000 per square kilometre (/km$^2$) where 97.2% of people self-identify as 'Coloured' (Census, 2011). Between 2010 and 2020 property prices ranged from as little as 0.45 million South African Rand (ZAR) (two-bedroom house) to around 1.3 million ZAR or 84 500 USD (5 – 6 bedroom house) (Property24, 2021a).

### 3.1.2 DIEP RIVER CLINIC

Diep River Clinic is a government primary health care clinic that provide free services as part of the City of Cape Town's Health Sector. Primary health care at this facility includes pre- and neonatal consultations, immunisations, family planning (consultations and dispensing of contraceptives), and consultations for sick children up to the age of 12 years. HIV and tuberculosis screening, counselling and medication is offered. This primary health care clinic is situated in the suburb of Diep River, City of Cape Town, Western Cape Province, SA. The suburb has an area of 0.75 square kilometre (km$^2$) and its population density is approximately 3 342 per square kilometre (/km$^2$) (Census, 2011). Persons of MA comprise the second largest (24.8%) population group in the area (Census, 2011) whereas 62.0% of individuals in this community are of European descent. Between 2016 and 2020 property prices ranged from a minimum of 1.2 million ZAR (78 000 USD) to approximately 5 million ZAR (325 000 USD) (Property24, 2021b).

### 3.1.3 MELOMED TOKAI PRIVATE HOSPITAL

MeloMed Tokai is a private hospital with private consultation suites for doctors who are specialists in medical fields ranging from neurologists to paediatricians. The primary health care clientèle, or patients if hospitalisation is required, can either pay cash or use their medical aid schemes to pay for pre- and post-natal consultations, hospitalisation for birth, immunisations and paediatric consultations for common or chronic illnesses with the paediatrician. None of the services at MeloMed Tokai Private Hospital are free. It is located in the suburb of Tokai, but the clientèle is not restricted to this particular suburb. The participants for this study reside within the suburb of Tokai or the surrounding areas. This large suburb is situated at the foothills of Constantiaberg, City of Cape Town, Western Cape Province, SA, surrounded by other suburbs such as Steenberg, Kirstenhof, Bergvliet and Constantia. The suburb has an area of 1.05 square kilometre ($km^2$) and its population density is approximately 2 400 per square kilometre ($/km^2$) (Census, 2011). Between 2016 and 2020 property prices ranged from a minimum of 3 million ZAR (195 000 USD; 2 bedroom house) to approximately 11 million ZAR (715 000 USD; 4 bedroom house) (Property24, 2021c).

### 3.1.4 PARTICIPANT RECRUITMENT, CONSENT, AND IDENTIFICATION

Participants were approached while waiting to be seen by the paediatric staff. The research was explained to each potential maternal participant, its significance to the specific community at large, and the terms of consent to participate in the research (Figure D.1). Once they understood, and if they were willing to participate, informed consent procedures were executed. Only one mother withdrew after giving consent.

Mothers or primary caregivers were asked for consent (Figure D.2) to collect both the anthropometric measurements of their child, and to answer the questionnaire, providing context concerning medical and early childhood environmental factors that may have influenced their child's growth and development. The questionnaire data included information concerning both the child, his/her mother, and some paternal information that was obtained from the mother/legal guardian. Each dyad pair (mother and child) participating, was allocated a unique identifying number associated with the research location, age cohort and order in which they were recruited, *i.e.* research location-age cohort-collection number (Table 3.1).

**Table 3.1: Participant identification protocol.**

| Code | Description |
|---|---|
| | **Research location** |
| 01 | Diep River Clinic |
| 02 | Bishop Lavis Clinic |
| 03 | MeloMed Tokai Private Hospital |
| | **Age cohort** |
| 01 | 0 to 5.9 months |
| 02 | 6 to 11.9 months |
| 03 | 12 to 18 months |
| | **Collection number** |
| 00 – 50 | Number of participants |

The identification number was assigned to ensure anonymity when working with the data, and future researchers who may want to use the baseline data for further research. All consent forms had the associated identification number, and if a mother wished to withdraw consent the number identified which data set was to be removed if participation consent withdrawal happened a few days later.

### 3.1.5 EXCLUSION CRITERIA

The following factors were considered exclusion criteria as they are known to impact physical growth, neurological development, and nutritional intake during pregnancy and/or breastfeeding.

HIV-infected children and birth mothers were excluded from the study. Venkatesh *et al*. (2010) and Sutcliffe *et al*. (2012) both concluded that HIV-infected infants were twice as likely to be stunted and malnourished in the first three months of life as uninfected infants. Venkatesh *et al*. (2010) also noted that HIV-infected mothers would stop breast feeding, which may be a significant contributor to the malnourished state of infants and infant mortality. Sutcliffe *et al*. (2012) showed that even after a two-year period of antiretroviral therapy treatment, infants remained underweight and below the ‘norm’ for height. HIV testing results (within 3 months of the visit) is a prerequisite at the public health centre and clinic and this information is documented in the case files for all mothers and children. Therefore, the HIV status of participants were known.

Children diagnosed with foetal alcohol syndrome, or partial foetal alcohol syndrome were also excluded from the study. Conclusions drawn by Carter *et al.* (2012) stated that prenatal exposure to severe alcohol consumption by birthmothers resulted in reduced weight, length, and head circumference of neonates. Even in the event of food security, these measures do not return to the ‘norm’ of a growth and development phase. During the survey, mothers were asked if they consumed alcohol during pregnancy and/or the breastfeeding period, and the frequency of consumption if they answered yes. Based on this self-reporting information, one dyad pair was excluded as the mother reported daily consumption during pregnancy and breastfeeding. Most mothers that indicated they consumed alcoholic beverages, specified “rarely” in a year cycle. Further elaboration indicated that consumption was between 250 – 500 ml per occasion and never more than five times per 365 days. Excluding the one dyad pair, most mothers who consumed alcoholic beverages stated that once their pregnancy was either suspected or confirmed, they stopped consuming alcohol for the duration of the pregnancy and during breastfeeding.

Children from birth mothers with a history of drug use/abuse were also excluded. Behnke and Smith (2013) reviewed the effect(s) various substances (from nicotine to opiates) have on different developmental characteristics in children and concluded that growth was adversely affected by substance use/abuse during the prenatal phase (FAQ 170, The American College of Obstetricians and Gynecologists, 2017). Adverse side effects include preterm births, low birth weight, neonatal abstinence syndrome and maternal mortality (Centers for Disease Control and Prevention, 2022).

According to Moore *et al*. (2010) children who have suffered from severe and prolonged illnesses may have severely affected weight-for-age and height-for-age z-scores, and therefore, these children were not included in the study.

Preterm babies (those born before 37 weeks gestational age) were also not enrolled in the study as their growth and developmental phases do not conform to the ‘norm’ set by the WHO MGRS (Fenton *et al*., 2013). The WHO inclusion criteria states that term births are defined as equal or greater than 37 gestational weeks to less than 42 gestational weeks; and those children should be from single births; *i.e*. no twins, triplets *etc*. (De Onis *et al*., 2006). Therefore, only single births were included in the study data.

### 3.1.6 CONFOUNDING FACTORS

Potential confounding factors and explanatory variables were incorporated into the questionnaire and subsequent analysis, to determine if they were related to or had the potential to impact on growth trajectory. These included factors such as: the number of dependent children the birthmother had, her employment status, education attainment, the availability of sanitation and water in the home, immunisations and/or booster drops administered later than age-appropriate appointments, and mothers who smoked during pregnancy and/or during breastfeeding.

Most growth studies exclude participants who smoked during pregnancy and/or breastfeeding. This study included these participants to assess the confounding effect this may have had on growth. As an estimated 38% of MA women smoke according to the National Department of Health (2017), it was deemed necessary to collect data for both non-smoking and smoking mothers. Birthmothers were asked whether they smoked, and if yes, to what extent during pregnancy and/or the breastfeeding period.

## 3.2 METHODOLOGY

This study was designed using quantitative (anthropometric measurements) and survey data (two questionnaires) to assess growth of MA children for the specified age cohorts and the potential impact external environmental conditions may have on their growth.

It was found that completing the questionnaires first, followed by the anthropometric measurements, worked best as most infants were sleeping or in a restful state when the mothers were approached to participate in the study. Older children in the 12 – 18 months of age category had time to settle into the environment and ease their anxiety before the anthropometric measurements were taken.

The measurement instrumentation used was the standard equipment used at the University of Cape Town following international guidelines. All three pieces of equipment, namely the weight scale, length measurement mat and the metal tape for head circumference, were tested prior to data collection with other calibrated equipment. The reading error was less than 1%.

### 3.2.1 ANTHROPOMETRIC MEASUREMENTS

Anthropometric measurements were taken in the following order to lessen agitation of the infants, and thereby to ensure more accurate measures: (i) head circumference, (ii) length/height, and (iii) weight. These measurements were collected three times, where possible, and the average measurements were used for statistical analyses. For the head circumference measurement, children were seated on their mother's lap, still fully clothed and could be soothed by their mothers if frightened. The length measurement then required removal of all heavy layers of clothes, shoes, socks and loosening of nappy or complete removal of it. Finally, the weight measurement also required removal of vests and/or long-sleeved tops, and the nappy. The sequence minimised the amount of time that a child was exposed to cold temperatures and made it easier to ask for repeated measurements, especially when a child became irritable during measurements. The head circumference measurement caused the most agitation as children from the older age cohort (12 – 18 months) did not like the metal measurement tape around their heads. Only 3.1% (5/161) of all children whose measurements were taken would not sit still for a third measurement and kept moving their heads to remove the metal tape. In these cases, only two measurements could be accurately determined and recorded. The anthropometric measurements were collected according to the following descriptions by De Onis *et al.* (2004c), De Onis *et al*. (2006) and Foote (2014) as summarised in Table 3.2.

**Table 3.2: Measurement protocol (De Onis *et al.*, 2004c; De Onis *et al.*, 2006; Foote, 2014).**

| Measurement | Description | Unit |
|---|---|---|
| Head circumference | The child's hair was loosened, and all hair accessories were removed. The metal tape measure was placed and held just above the eyebrows with the tape wound around the head across the fullest protuberance of the external occipital protuberance or inion. The tape was pulled tight to press against the hair and the measurement was taken. This procedure was repeated three times for each child, unless they became agitated. | cm |
| Length | An infantometer, range 0 cm to 110 cm, board was used. The infant was laid down with the head in the Frankfort plane at the stationary end of the measuring board. The infant's head was held in place (crown of the child's head was to touch the stationary end of the board) by the mother (Foote, 2014). The shoulders and hips were placed at a right angle (90˚) to the long axis of the body. The lower limbs were straightened (nappy must be loose or completely removed if it impedes correct measurement) by the candidate with gentle pressure being applied on the knees. The soles of the feet were placed against the moveable end of the board (toes facing upwards). | cm |
| Weight | Weight was measured using a Seca scale as recommended by the World Health Organization. All clothing, including the nappy, was removed and the measurement was taken without assistance (mother did not hold the infant in any manner). | kg |

cm = centimetre kg = kilogram

### 3.2.2 QUESTIONNAIRES

The questionnaires were developed to gain insight into how socio-economic and socio-ecological factors may contribute to the growth trajectory of these children, particularly when comparing those from mid-to-upper SES backgrounds to those from low SES backgrounds. The research intended to analyse length-for-age, weight-for-age, weight-for-length-for-age and head circumference-for-age z-scores between the SES groups. Furthermore, the research also intended to analyse the relative contributions of maternal, and in a broader sense familial and socioecological factors that may possibly influence the growth (health and wellbeing) of these children. Paternal information collected were obtained from the mother, irrespective of living arrangements.

#### 3.2.2.1 Development of the socio-demographic, socio-economic and medical history information questionnaire

Education, income, employment and household occupancy (number of adults and children) questions were based on definitions and descriptors recommended by the American Psychology Association (https://www.apa.org/pi/ses/resources/class/measuring-status, 2018). Medical questions were based on required information to complete the Road-to-Health (RtH) booklet such as gestation period, feeding method (and duration), immunisations, illness history, HIV status, tuberculosis exposure *etc*. (https://sidebyside.co.za/resources/road-to-health-book/, 2018).

Questions pertaining to socio-demographic and socio-economic factors such as parental age, maternal education, household occupancy (number of adults and children living on a single residential property), residential proprietorship, employment status, annual income levels (termed salary scale in this thesis), number of maternal dependents, and food consumption, were included in questionnaire in section A of Appendix E.1. Sanitation and water source were also included as it pertains to differences that might be found between formal urban residential areas, informal urban areas and rural areas in South Africa (Zere and McIntyre, 2003; Faber, 2007; Faber *et al*., 2015; Senekal *et al*., 2019; Sartorius *et al*., 2020). This enabled the candidate to analyse which of these factors, if any, might have played a role in the variance of linear growth for this study's infant cohort. Socio-economic factors may be indicative of socio-demographics and socio-political influences as is the case in South Africa. Hence, the reason these questions were included in the questionnaire. Other researchers have included all of these factors that enabled them to establish which factors might have contributed to growth rates in various international and local population groups, and differences in rural and urban settings. All these research studies were previously discussed in the literature review of this thesis.

Information regarding maternal health during pregnancy and the breastfeeding period is vital to know as it would garner better understanding as to what may have caused growth faltering, if any. As with the exclusion criteria in subsection 3.1.5 in this chapter, knowledge of the effect HIV, tuberculosis, alcohol consumption, smoking, drug use would have on foetal development and during the breastfeeding period, informed exclusion of some of the dyad pairs. The candidate was aware of the emotional sensitivity most of these questions would cause in a public space. To allow personal dignity of mothers, the candidate did not mention that they would be excluded during data collation. It was also necessary to know if there were any complications of the mother's health during pregnancy such as gestational diabetes and hypertension. Hence, specific questions in section B number 8.3 of Appendix E.1 pertaining to the mother's general health was asked.

Questions pertaining to medical care cost in section B number 7 of Appendix E.1 had a dual purpose. First, it is indicative of the availability of disposable financial resources. Secondly, the means to access immediate private medical care when an infant is ill, prevents the illness to cause a lasting effect on linear growth. It is important to understand that in South African public primary health care facilities the waiting period to see a professional nurse can be between 2 – 4 hours. It is for this reason mothers who do not have the financial resources to seek private medical care for their infants, delay seeking medical assistance at these public health care facilities and resort to over-the-counter medication first (candidate's personal communication with mothers during the interview period).

Questions pertaining to the infant's feeding, illnesses, diagnosed diseases, immunisations, deworming and vitamin booster consumption were important information. Infants with chronic illness such as diarrhea or sinusitis were excluded. This information was only available after the interview process and allowed the candidate to remain sensitive to a mother's emotional wellbeing. Therefore, subsection B number 8.1 of Appendix E.1 allowed for exclusion of specific dyad pairs without the candidate having prior knowledge of the infant's health condition. It was important to ensure any mother who consented to partake in the research, had her dignity unaffected.

Appendix E.1 included questions regarding the types of food that was consumed by all individuals in the household. This was deemed important in conjunction with the food security and availability questionnaire (Appendix E.2) as it informed the candidate that although many mothers did not report regular food shortages, the food consumed were not always nutrient-rich. The importance of nutrient-rich food or the lack thereof, was highlighted by Faber *et al*. (2015) and Du Plessis *et al*. (2016) as a factor of persistent malnutrition. Hence, the reason daily food consumption questions were included in subsection A number 5 of Appendix E.1, to give further insight to the food security and availability questionnaire.

3.2.2.2 Socio-demographic and -economic information questionnaire

Information from the SES questions assessed the living environment in which the children were being reared, and to understand various factors that may possibly influence their growth trajectory (Figure E.1, Appendix E – section A). For example, to understand the financial situation of the home, it was important to know how many individuals resided in a house (household occupancy), how many of these individuals were working, and therefore contributing to living expenses, or, if water sources were readily available for drinking and cleaning. Another issue was the number of dependent children for which the mother had to provide, and how that may have impacted household food security (quality and quantity).

3.2.2.3 Medical history information questionnaire

Information from questions in this section were designed to understand factors directly impacting the health of mothers during pregnancy, infants after birth and mothers during breastfeeding (or not breastfeeding) (Figure E.1, Appendix E – section B). The questions related to the mother's social health issues (*e.g.* did she smoke, drink or use drugs), clinical health concerns (*e.g.* chronic diarrhoea, gestational diabetes, hypertension, and other health issues), and/or familial chronic diseases and/or disorders that may have potentially affected the foetus during pregnancy or the infant after birth, during breast feeding and/or since breastfeeding stopped.

It was important to obtain detailed accounts of the clinical health issues these children faced within this growth period that could have negatively affected their growth. Hence, all health issues pertaining to the child, whether it was chronic or they had a quick recovery, were noted the severity and medications that were either prescribed or bought over the counter. Multiple cases of the same health issue were noted.

3.2.2.4 Food security and dietary quality questionnaire

Information regarding food security and dietary quality were collected using Coates *et al*.'s (2007) "*Household Food Insecurity Access Scale*" (HFIAS) (Figure E.2, Appendix E).

Additionally, mothers were asked to indicate how long children were exclusively breastfed, the age of the child when complementary solid foods were introduced and the types of complementary food given (question 8.1, section B, Figure E.1, Appendix E).

Maternal nutrient-rich nourishment during the ante-natal phase is important for foetal development and influences production of nutrient-rich breastmilk for the infant when breastfeeding. Thus, it was an important criterion included in the WHO MGRS, and if there was a lack of nutrient-rich food, fieldwork assistants provided participating mothers with adequate nutrient-rich food (De Onis *et al*., 2004a; De Onis *et al*., 2004b). This was not possible in this study. Therefore, gaining a general insight to the quality of nutritional consumption reported in the HFIAS, number 5 in subsection A of Appendix E.1 was added. In this study, the nutritional information gathered was a means to better understand the nutritional quality of food consumed in a household. The data collected was not statistically analysed in this study, but will be used in future for secondary analysis of socio-economic factors that have greater influence on linear growth of infants in the latter half of the first 1 000 days of life.

## 3.3 DATA COLLATION AND STATISTICAL ANALYSES

### 3.3.1 Intra- and inter-observer error

Re-measurements of the length, weight, and head circumference of 20 infants (four every day for five days consecutively) were taken by the candidate and an independent observer, Professional Nurse Michelle Ambrose at Bishop Lavis Clinic.  The mean difference, upper limit (mean difference + 1.96 x standard deviation) and lower limit (mean difference - 1.96 x standard deviation) of the mean difference was calculated using the interrater reliability test of Bland Altman (Excel, Windows 10). For inter-observer error, a one-sample *t*-tests of the mean difference between the candidate's first measurements (length, weight, head circumference), and her second measurements (intra-observer error) were run to find whether there was a significant difference between the two measures. Then the process was repeated for the candidate's first measurement and the independent observer's measurements (inter-observer error).

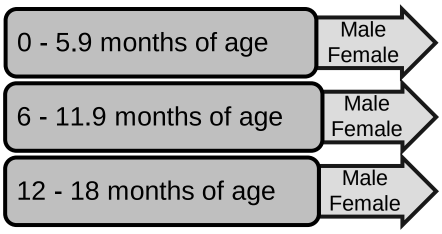
### 3.3.2 Anthropometric measurements and z-score data

Each participant's identification number, anthropometric measurements and age in months were entered into Excel. Once all data were entered, these spreadsheets were imported on the website https://apps.cpeg-gcep.net/igrowup_cpeg/ where anthropometric measurements were converted to z-scores according to the World Health Organization's equations and tables. These z-scores were then entered into the Excel spreadsheet.

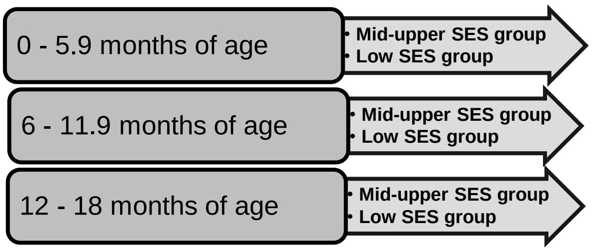
Anthropometric measurements and z-scores were captured per SES group per age group in Excel, then all information from the questionnaires were captured, and the qualitative data (nominal and ordinal variables) were coded for use in IBM® SPSS® Statistics version 27 (2020) which was used for all data analyses. All alpha values (*p*-values) of less than or equal to 0.05 ($p \leq 0.05$) indicated a significant difference and were highlighted in the Tables that presented results of various statistical analyses. In addition, Bonferroni alpha values were calculated to correct for Type I errors (Armstrong, 2014).

Descriptive statistics such as mean, standard error of mean (SEM), median (distribution of data), standard deviation (SD), minimum and maximum were determined for infant ages. Mean and SD of the anthropometric measurements and z-score results were grouped as follows, which correspond to Tables 4.2 and 4.3, respectively, in the results chapter:

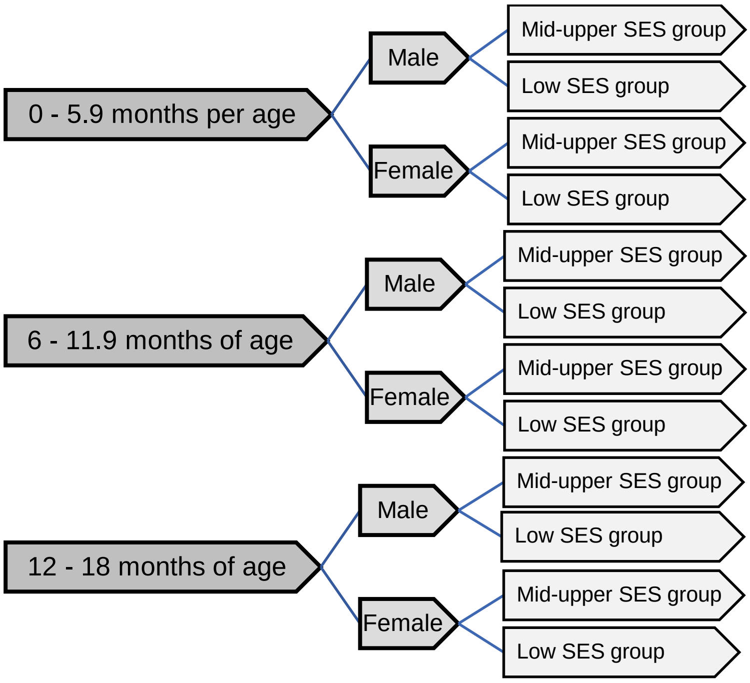
- ❖ 0 – 18 months of age: all males versus all females (irrespective of age or SES group)
- ❖ Age group per sex: (irrespective of SES group)




- ❖ Age group per SES group (irrespective of sex)



❖ Per age group per sex group per SES




Analysis of variance (or ANOVA) tests were applied to grouped mean data for the anthropometric and the z-score data to calculate if significant differences existed between each of the groups as described above. In addition, Bonferroni adjusted alpha values were calculated and highlighted in these tables.

3.3.3 Parental age, medical history, and socio-economic information of participants

All data (continuous, nominal or ordinal) from the questionnaires were captured, and the nominal and ordinal variables were coded in Excel® prior to importing the spreadsheet into SPSS® for analyses. In Table 3.3 each variable used from the questionnaires was identified as a continuous, nominal, or ordinal variable. The nominal and ordinal data were reported as frequencies and percentages rather than totals for each of the SES groups as participant numbers were unequally distributed between the groups.

Pearson correlations were run for each of the z-scores (length-for-age, weight-for-age, weight-for-length-for-age, and head circumference-for-age) with all continuous variables from the questionnaires as indicated in Table 3.3, whereas Spearman's rho correlations were run for each z-score with all ordinal variables. Eta coefficients were calculated for nominal-continuous data to determine the amount of variance in the dependent sample, the strength of association, and if applicable, a Chi-Squared test was performed to test significant differences.

**Table 3.3: An indication of what type of variable (continuous, nominal or ordinal) each of the explanatory variables were that prescribed the statistical test performed in SPSS® version 27 (2020). In SPSS® a continuous variable was indicated as a scalar variable.**

| Explanatory variable | Type of variable | | |
|---|---|---|---|
| | **Continuous** | **Nominal** | **Ordinal** |
| Maternal age (years) | ✓ | | |
| Paternal age (years) | ✓ | | |
| Number of dependents of mother | ✓ | | |
| Household occupancy | ✓ | | |
| | | | |
| Maternal education (years) | ✓ | | |
| Salary scale | | | ✓ |
| Does the mother have employment? | | ✓ | |
| Medical care cost | | | ✓ |
| | | | |
| Gestational age (weeks) | ✓ | | |
| Weight at birth | | ✓ | |
| Exclusive breastfeeding duration (months) | ✓ | | |
| Infant age when solid (complementary) food products introduced into infant diet | ✓ | | |
| Infant age when infant diet contains more solid food products than milk products | ✓ | | |
| | | | |
| Maternal smoking – general lifestyle | | ✓ | |
| Maternal smoking during pregnancy | | ✓ | |
| Maternal smoking during breastfeeding period | | ✓ | |
| Maternal drinking during pregnancy | | ✓ | |
| Maternal drinking during breastfeeding period | | ✓ | |
| | | | |
| **Infantile** health issues: Diarrhea | | ✓ | |
| Nasal infections | | ✓ | |
| Chest infections | | ✓ | |
| Jaundice | | ✓ | |
| Ear infections | | ✓ | |
| Common cold | | ✓ | |
| | | | |
| **Maternal** pre-natal health issues: Gestational -/diabetes | | ✓ | |
| Hypertension | | ✓ | |
| Urinary tract infections | | ✓ | |
| Other health issues | | ✓ | |
| Pregnancy weight gain | | ✓ | |
| | | | |
| HFIAS score = b + c + d (scores for questions) →Insufficient quality of food types (variety and preferences) | ✓ | | |
| HFIAS score = e + f + g + h + i (scores for questions) →Insufficient food intake and its physical consequences | ✓ | | |
| HFIAS score = **Σ** a – i = Total score (27) | ✓ | | |

Nominal variable ↔ Dichotomous variable

HFIAS = Household Food Insecurity Access Scale
HFIAS a – i : Letter of question on the HFIAS

**Σ** a – i = Sum of scores for Questions a to i on the HFIAS

Other statistical testing included Kruskal Wallis, Mann-Whitney U and independent sample median tests to determine if there were associations between variables. To test multicollinearity between variables, the variance inflation factor (VIF) was determined. Although variables may not be collinear, they could have been proxy variables for each other such as gestational age (weeks) and weight at birth, or maternal age (years) and maternal education (years), or maternal age (years) and paternal age (years).

3.3.4 Linear regression model analysis

Results from the nonparametric tests and the bivariate analyses were used to identify explanatory variables that would be entered into the regression model analyses. For each of the z-score parameters only those explanatory variables that showed significant correlations or associations were included in the regression model analyses.

For each of the models presented in the results chapter, the R value, adjusted $R^2$ value, F-value (F) with its significant factor (*p*), and each explanatory variable's standard beta coefficient (β) with their significance factor (*p*) were given based on the model summary and coefficient results in SPSS®.

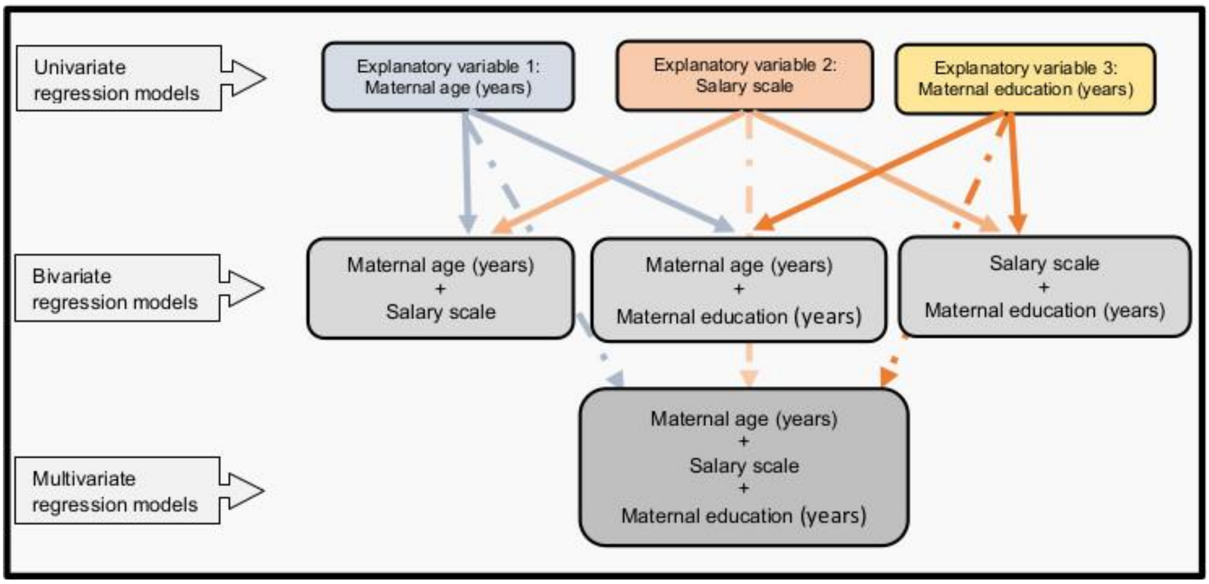



**Figure 3.2: Process depicting how explanatory variables were used to run uni-, bi- and multivariate regression models.**

# CHAPTER 4: RESULTS

Results in this chapter were subdivided into three components. Subsection 4.1 encompassed the anthropometric measurements and z-score results of the sample population group, subsection 4.2 dealt with the information obtained from the different questionnaires, and subsection 4.3 the univariate and multivariate regression analyses.

## 4.1 ANTHROPOMETRIC MEASUREMENTS

Interrater reliability indicated that there were no significant differences for intra- and inter-observer error. Results in this subsection represent descriptive statistics and ANOVA analyses for the anthropometric measurements (*i.e*. length, weight and head circumference) and z-scores (*i.e*. length-for-age, weight-for-age, weight-for-length-for-age, and head circumference-for-age). Data are presented for the overall age cohort of 0 – 18 months of age (months) for each of the sexes, and then separated into the various categories as previously stated, *i.e*. per age group, per socio-economic status (SES) group, and lastly each age group was subdivided into sex per SES group.

### 4.1.1 DESCRIPTIVE STATISTICS

Descriptive data pertaining to the infant cohort are presented in Table 4.1. A total of 180 participants were successfully recruited of which 161 were included in the final statistical analysis. There were nineteen (19) participants who were excluded based on the following criteria: five (5) infants were pre-term (gestational age of less than 37 weeks), four (4) infants were positive for human immunodeficiency virus (HIV)/acquired immunodeficiency syndrome (AIDS), one (1) infant's mother reported excessive consumption of alcohol during pregnancy and breastfeeding period, and nine (9) infants were not included as they were older than 18 months. The initial age cohort were defined as 0 – 36 months, but after 6 weeks of data collection it was determined that very few children older than 18 months visited the public health care facilities as they did not require immunisation between 18 months and 72 months. Only children who were sick were in attendance, and therefore, the age cohort was redefined after this initial data collection period. The remaining 161 participants that were included were aged 0 – 18 months and were further subdivided into three age groups: (i) 0 – 5.9 months, (ii) 6 – 11.9 months, and 12 – 18 months. In total, there were 71 males (44.1%) and 90 females (55.9%). The age group distribution is represented in Table 4.2. In the age group 0 – 5.9 months there were 68 (42.2% of 161) participants of which 20 were from the MU-SES group, and 48 from the L-SES group. In the age group 6 – 11.9 months, there were a total of 58 (36.0% of 161) participants of which 16 were from the MU-SES group, and 42 from the L-SES group. In the last age group, 12 – 18 months, there were 35 (21.7% of 161) participants of which 10 were from the MU-SES group, and 25 from the L-SES group.

The mean age (Table 4.1) for the age group 0 – 5.9 months was 2.47 months (or 10.69 weeks) with a minimum age of 0.46 months (or 2 weeks) and a maximum age of 5.75 months (or 25 weeks). For the age group 6 – 11.9 months, the mean age was 7.75 months with 6 months as the youngest and 10 months as the oldest participant in this group. The age group 12 – 18 months had a mean age of 14.70 months with a minimum age of 12 months (or one year) and a maximum of 18.00 months.

**Table 4.1: Descriptive statistics of the participants' ages (in months) for each socio-economic status (SES) background group, age group and sex.**

| Descriptive statistics for age | Socio-economic status background | | Age cohorts | | | Sex | |
|---|---|---|---|---|---|---|---|
| | MU-SES | L-SES | Months of age (months) | | | Male | Female |
| | | | 0 - 5.9 | 6 - 11.9 | 12 - 18 | | |
| No. of Participants | 47 | 114 | 68 | 58 | 35 | 71 | 90 |
| Mean (months) | 7.43 | 6.87 | 2.47 | 7.75 | 14.70 | 7.22 | 6.88 |
| SEM (months) | 0.71 | 0.47 | 0.14 | 0.20 | 0.47 | 0.58 | 0.54 |
| Median (months) | 6.23 | 6.00 | 2.30 | 8.73 | 13.00 | 6.00 | 6.00 |
| SD (months) | 4.87 | 5.05 | 1.12 | 1.53 | 2.76 | 4.85 | 5.11 |
| Minimum (months) | 0.69 | 0.46 | 0.46 | 6.00 | 12.00 | 0.46 | 0.46 |
| Maximum (months) | 18.00 | 18.00 | 5.75 | 10.00 | 18.00 | 18.00 | 18.00 |

**SEM = Standard Error of Mean SD = Standard Deviation MU-SES = Mid-to-Upper SES Low SES = L-SES**

### 4.1.2 ANTHROPOMETRIC DATA AND Z-SCORE RESULTS

The original measurements; *i.e.* length, weight and head circumference; of each infant have been included in Appendix I. As stated previously, each anthropometric measurement was taken three times and the average for each measurement was used for statistical analyses. Results for each anthropometric measurement, were described, according to the total age cohort (0 – 18 months) subdivided into the three age groups per sex, then each age group by SES group, and finally each age group by sex and SES group, highlighting where statistically significant differences exist between specific groups. In addition, the anthropometric data were analysed as z-scores or standard deviations from the median (0), based on the WHO MGRS 2006 international growth standards. The z-scores were described for the entire sample, and then in a sub-group analysis, similar to the raw anthropometric measurements. Interpretation of z-scores was based on the growth indicator table as presented in Figure 4.1.

| Z-score | Growth indicators | | |
|---|---|---|---|
| | Length-for-age | Weight-for-age | Weight-for-length-for-age |
| Above 3 | See note 1 | | Obese |
| Above 2 | | | Overweight |
| Above 1 | | See note 2 | Possible risk of overweight (see note 3) |
| 0 (median) | | | |
| Below -1 | | | |
| Below -2 | Stunted (see note 4) | Underweight | Wasted |
| Below -3 | Severely stunted | Severely underweight (see note 5) | Severely wasted |

**Notes:**
**1.** A child in this range is very tall. Tallness is rarely a problem, unless it is so excessive that it may indicate an endocrine disorder such as a growth-hormone-producing tumour. Refer a child in this range for assessment if you suspect an endocrine disorder (*e.g.* if parents of normal height have a child who is excessively tall for his or her age).
**2.** A child whose weight-for-age falls in this range may have a growth problem, but this is better assessed from weight-for-length/height or BMI-for-age.
**3.** A plotted point above 1 shows possible risk. A trend towards the 2 z-score line shows definite risk.
**4.** It is possible for a stunted or severely stunted child to become overweight.
**5.** This is referred to as very low weight in IMCI training modules. (Integrated Management of Childhood Illness, In-service training. WHO, Geneva, 1997).

*Extract taken from* "Interpreting Growth Indicators" *(page 14) of the Training Course on Child Growth Assessment.*

**Figure 4.1: A growth indicator table for length-for-age, weight-for-age and head circumference-for-age z-scores as taken from the '*Training Course on Child Growth Assessment'* (World Health Organization, 2008).**

4.1.2.1 LENGTH

For the full infant cohort of 0 – 18 months there was no significant difference between the sexes as seen in Table 4.2 (anthropometric measurements) and Table 4.3 (z-scores). There were also no significant differences in length for all participants older than 6 months of age in each of the categories as shown in Tables 4.2 and 4.3; *i.e.* between the sexes (male and female), per SES group (MU-SES versus L-SES, irrespective of sex), and per sex per SES group. The z-scores for the full infant cohort and those older than 6 months show the same results for length-for-age.

For the 0 – 5.9 months age group, females appeared to be shorter than their male counterparts (female mean: 57.3 cm vs male mean: 59.6 cm, p=0.021) (Table 4.2). L-SES infants were found to be shorter than MU-SES infants in this age group (L-SES mean: 57.2 cm vs MU-SES mean: 60.7 cm, p=0.001) (Table 4.2), and this remained significantly different when the Bonferroni alpha value of 0.004 was applied. For each of the sexes per SES group, both L-SES males and females were shorter than their MU-SES counterparts (Table 4.2).

**Table 4.2: Descriptive statistics and ANOVA *p*-values for anthropometric measurements for different categories per age group as indicated.**

| Category & age group | | Category description | | N | Length (cm) | | | Weight (kg) | | | Head circumference (cm) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Mean | SD | *p* | Mean | SD | *p* | Mean | SD | *p* |
| Total age cohort | 0 – 18 months | Male | | 71 | 68.1 | 8.6 | 0.127 | 7.95 | 2.42 | 0.084 | 43.3 | 3.7 | **0.023*** |
| | | Female | | 90 | 65.9 | 9.1 | | 7.28 | 2.38 | | 42.0 | 3.7 | |
| | 0 - 5.9 months | Male | | 28 | 59.6 | 4.2 | **0.021*** | 5.82 | 1.31 | **0.008*** | 39.6 | 1.9 | **0.012*** |
| | | Female | | 40 | 57.3 | 3.8 | | 5.06 | 1.02 | | 38.5 | 1.8 | |
| | 6 - 11.9 months | Male | | 28 | 70.6 | 3.2 | 0.259 | 8.72 | 1.86 | 0.370 | 44.9 | 2.1 | 0.083 |
| | | Female | | 30 | 69.6 | 3.4 | | 8.37 | 1.08 | | 44.0 | 1.7 | |
| | 12 – 18 months | Male | | 15 | 79.4 | 4.5 | 0.281 | 10.46 | 1.49 | 0.486 | 47.4 | 1.3 | **0.017*** |
| | | Female | | 20 | 77.8 | 4.1 | | 10.11 | 1.42 | | 46.1 | 1.6 | |
| Socio-economic status (SES) group | 0 - 5.9 months | Mid-to-Upper SES | | 20 | 60.7 | 3.9 | **0.001*ᴮ** | 5.79 | 1.11 | 0.061 | 39.8 | 1.9 | **0.024*** |
| | | Low SES | | 48 | 57.2 | 3.7 | | 5.20 | 1.20 | | 38.6 | 1.9 | |
| | 6 - 11.9 months | Mid-to-Upper SES | | 17 | 70.6 | 3.8 | 0.482 | 8.82 | 1.79 | 0.384 | 44.7 | 2.5 | 0.520 |
| | | Low SES | | 41 | 69.9 | 3.2 | | 8.43 | 1.39 | | 44.3 | 1.7 | |
| | 12 – 18 months | Mid-to-Upper SES | | 10 | 79.6 | 3.4 | 0.306 | 10.62 | 1.33 | 0.355 | 47.0 | 1.8 | 0.460 |
| | | Low SES | | 25 | 78.0 | 4.5 | | 10.12 | 1.48 | | 46.5 | 1.5 | |
| Sex / SES group | 0 - 5.9 months | Male | Mid-to-Upper SES | 6 | 63.6 | 2.5 | **0.006*** | 6.56 | 0.88 | 0.119 | 41.4 | 1.5 | **0.007*** |
| | | | Low SES | 22 | 58.5 | 3.9 | | 5.63 | 1.35 | | 39.2 | 1.7 | |
| | | Female | Mid-to-Upper SES | 14 | 59.5 | 3.8 | **0.006*** | 5.46 | 1.06 | 0.063 | 39.1 | 1.6 | 0.130 |
| | | | Low SES | 26 | 56.1 | 3.3 | | 4.84 | 0.94 | | 38.1 | 1.9 | |
| | 6 - 11.9 months | Male | Mid-to-Upper SES | 9 | 71.0 | 2.9 | 0.675 | 9.30 | 1.94 | 0.308 | 45.3 | 2.5 | 0.472 |
| | | | Low SES | 19 | 70.4 | 3.4 | | 8.49 | 1.82 | | 44.7 | 2.0 | |
| | | Female | Mid-to-Upper SES | 8 | 70.2 | 4.7 | 0.598 | 8.34 | 1.59 | 0.937 | 44.0 | 2.5 | 0.946 |
| | | | Low SES | 22 | 69.4 | 2.9 | | 8.38 | 0.87 | | 44.0 | 1.3 | |
| | 12 – 18 months | Male | Mid-to-Upper SES | 2 | 81.1 | 5.5 | 0.567 | 10.70 | 2.32 | 0.816 | 47.7 | 0.5 | 0.703 |
| | | | Low SES | 13 | 79.1 | 4.5 | | 10.42 | 1.46 | | 47.3 | 1.4 | |
| | | Female | Mid-to-Upper SES | 8 | 79.3 | 3.1 | 0.188 | 10.60 | 1.22 | 0.215 | 46.8 | 2.0 | 0.125 |
| | | | Low SES | 12 | 76.8 | 4.4 | | 9.78 | 1.50 | | 45.7 | 1.1 | |

***p* ≤ 0.05* indicates a significant difference** **N = Number of participants** **cm = centimetre** **kg = kilogram** **SD = Standard deviation**

**Bonferroni: *p*≤0.004ᴮ indicates significant difference.**

**Table 4.3: Descriptive statistics and ANOVA *p*-values for z-scores for different categories per age group as indicated.**

| Category | Age group | Category description | | N | Length-for-age (zlen) Mean | SD | *p* | Weight-for-age (zwei) Mean | SD | *p* | Weight-for-length-for age (zwfl) Mean | SD | *p* | Head circumference-for-age (zhc) Mean | SD | *p* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total age cohort | 0 – 18 months | Male | | 71 | -0.00 | 1.15 | 0.456 | -0.07 | 1.33 | 0.466 | -0.01 | 1.28 | 0.609 | 0.19 | 1.31 | 0.690 |
| | | Female | | 90 | 0.13 | 1.14 | | 0.07 | 1.03 | | 0.09 | 1.12 | | 0.27 | 1.06 | |
| | 0 - 5.9 months | Male | | 28 | -0.29 | 1.26 | 0.990 | -0.33 | 1.15 | 0.702 | -0.09 | 1.04 | 0.538 | -0.21 | 1.29 | 0.703 |
| | | Female | | 40 | -0.29 | 0.99 | | -0.43 | 0.88 | | -0.25 | 1.07 | | -0.10 | 0.97 | |
| | 6 - 11.9 months | Male | | 28 | 0.14 | 0.94 | 0.098 | 0.08 | 1.57 | 0.215 | 0.05 | 1.59 | 0.411 | 0.40 | 1.44 | 0.452 |
| | | Female | | 30 | 0.60 | 1.13 | | 0.50 | 0.91 | | 0.35 | 1.12 | | 0.64 | 1.02 | |
| | 12 – 18 months | Male | | 15 | 0.26 | 1.26 | 0.972 | 0.14 | 1.15 | 0.495 | 0.04 | 1.10 | 0.362 | 0.55 | 0.89 | 0.734 |
| | | Female | | 20 | 0.27 | 1.19 | | 0.41 | 1.10 | | 0.39 | 1.09 | | 0.43 | 1.08 | |
| Socio-economic status (SES) group | 0 - 5.9 months | Mid-to-Upper SES | | 20 | 0.28 | 0.80 | **0.005*** | -0.23 | 0.85 | 0.401 | -0.56 | 0.67 | 0.056 | 0.04 | 0.71 | 0.371 |
| | | Low SES | | 48 | -0.52 | 1.13 | | -0.45 | 1.05 | | -0.03 | 1.14 | | -0.22 | 1.23 | |
| | 6 - 11.9 months | Mid-to-Upper SES | | 17 | 0.23 | 1.14 | 0.520 | 0.37 | 1.45 | 0.808 | 0.41 | 1.60 | 0.491 | 0.50 | 1.74 | 0.923 |
| | | Low SES | | 41 | 0.43 | 1.04 | | 0.27 | 1.23 | | 0.13 | 1.27 | | 0.54 | 1.01 | |
| | 12 – 18 months | Mid-to-Upper SES | | 10 | 0.72 | 1.23 | 0.165 | 0.65 | 1.24 | 0.230 | 0.47 | 1.18 | 0.444 | 0.84 | 1.31 | 0.181 |
| | | Low SES | | 25 | 0.09 | 1.17 | | 0.15 | 1.05 | | 0.15 | 1.06 | | 0.34 | 0.82 | |
| Sex / SES group | 0 - 5.9 months | Male | Mid-to-Upper SES | 6 | 0.48 | 0.69 | 0.093 | -0.17 | 0.72 | 0.701 | -0.67 | 0.79 | 0.127 | 0.31 | 0.82 | 0.275 |
| | | | Low SES | 22 | -0.50 | 1.31 | | -0.38 | 1.25 | | 0.06 | 1.05 | | -0.35 | 1.37 | |
| | | Female | Mid-to-Upper SES | 14 | 0.19 | 0.85 | **0.023*** | -0.26 | 0.92 | 0.376 | -0.52 | 0.64 | 0.256 | -0.07 | 0.65 | 0.893 |
| | | | Low SES | 26 | -0.55 | 0.97 | | -0.52 | 0.86 | | -0.11 | 1.23 | | -0.12 | 1.11 | |
| | 6 - 11.9 months | Male | Mid-to-Upper SES | 9 | -0.07 | 0.78 | 0.470 | 0.47 | 1.71 | 0.420 | 0.69 | 1.80 | 0.179 | 0.51 | 2.00 | 0.801 |
| | | | Low SES | 19 | 0.22 | 1.01 | | -0.07 | 1.53 | | -0.21 | 1.47 | | 0.35 | 1.22 | |
| | | Female | Mid-to-Upper SES | 8 | 0.53 | 1.40 | 0.843 | 0.26 | 1.24 | 0.399 | 0.12 | 1.44 | 0.505 | 0.49 | 1.57 | 0.626 |
| | | | Low SES | 22 | 0.63 | 1.05 | | 0.59 | 0.78 | | 0.43 | 1.01 | | 0.70 | 0.78 | |
| | 12 – 18 months | Male | Mid-to-Upper SES | 2 | 0.56 | 1.24 | 0.736 | 0.15 | 1.58 | 0.992 | -0.14 | 1.39 | 0.818 | 0.64 | 0.07 | 0.885 |
| | | | Low SES | 13 | 0.21 | 1.31 | | 0.14 | 1.15 | | 0.07 | 1.11 | | 0.54 | 0.96 | |
| | | Female | Mid-to-Upper SES | 8 | 0.76 | 1.31 | 0.142 | 0.78 | 1.23 | 0.224 | 0.62 | 1.18 | 0.456 | 0.89 | 1.48 | 0.124 |
| | | | Low SES | 12 | -0.05 | 1.04 | | 0.16 | 0.98 | | 0.23 | 1.04 | | 0.13 | 0.61 | |

**$p \leq 0.05$* indicates a significant difference** **N = Number of participants** **SD = Standard deviation**

**Bonferroni: $p \leq 0.004^{B}$ indicates significant difference**

L-SES males in the 0 – 5.9 months age group were shorter than MU-SES males in the same age group (L-SES mean: 58.5 cm vs MU-SES mean: 63.6 cm). L-SES females in this age group were also shorter than MU-SES females (L-SES mean: 56.1 cm vs MU-SES mean: 59.5 cm) (Table 4.2). None remained significant once the Bonferroni alpha value was applied. Though the z-scores for the 0 – 5.9 months age group showed no significant difference between the sexes, irrespective of SES group, the L-SES group were shorter than the MU-SES group (L-SES mean z-score: -0.52 vs MU-SES mean z-score: 0.28), especially in the female cohort of this age group (L-SES females = - 0.55 vs MU-SES females = 0.19,) (Table 4.3). Yet again, they did not retain significance when the Bonferroni alpha value was applied.

Based on the overall length-for-age z-scores, 92.5% (149/161) of participants were between ±2 standard deviations (SD) from the WHO MGRS median (0) with less than 2.0% (3/161) of infants (2 males; 1 female) stunted and less than 1.0% of males (1/161) very stunted; all from the L-SES group (Figure F.1, Appendix F). Furthermore, results indicate that 5.0% (8/161) of the infants were above +2 SD of which 2 (1 male; 1 female) were above +3SD; both were from the L-SES group; and can be classified as very tall by WHO standards (Figure 4.1). Four of the 8 infants between +2 and +3 SD were females from the MU-SES group.

4.1.2.2 WEIGHT

4.1.2.2.1 Weight measurements and weight-for-age z-scores

For weight, only males in the 0 – 5.9 months age group weighed more than females based on the normal alpha value of $\leq 0.05$ (female mean: 5.06 kg vs male mean: 5.82 kg), irrespective of SES background (Table 4.2), but did not remain significant based on the Bonferroni alpha value of 0.004. Though the mean weights between the sexes (irrespective of SES) indicated a significant difference based on the normal alpha value (Table 4.2), this was not the case for the weight-for-length z-scores of the same age group between the sexes (Table 4.3). None of the other categories showed a significant difference between the means, irrespective of which alpha value was used.

Overall, 94.0% of all infants had weight-for-age z-scores between ±2SD (Table 4.3). The WHO growth indicators for weight-for-age only classify those for underweight (between -2 and -3SD) or severely underweight (below -3SD). Results showed that less than 2.0% (2/161) were underweight, and both were males from the L-SES group (Figure F.2, Appendix F). None of the infants were severely underweight. Furthermore, 4.3% (7/161) were above +2 SD of which 5 were male and mainly from the L-SES group (4/5).

#### 4.1.2.2.2 Weight-for-length-for-age z-scores

Wasting, overweight or obesity can be classified using the weight-for-length-for-age z-score (Figure 4.1). The WHO identifies wasting/severe wasting as below -2 SD from the median, and overweight/obesity as above +2 SD from the median based on weight-for-length-for-age z-score. Infants that could be at possible risk of becoming overweight fall between the +1 and +2 SD. Nearly 78.0% (125/161) of infants were of normal weight-for-length-for-age, *i.e*. between -2 and +1 SD, with 13.0% (21/161) at risk of being overweight (Figure F.3, Appendix F).

Only 5 infants (3.1 %; 3 males and 2 females) were classified as wasted or between -2 and -3 SD from the median of which 4 were from the L-SES group (Figure F.3, Appendix F). At the other extreme, only 5.0% (8/161) of the study cohort were overweight (between +2 and +3 SD) and less than 2.0% (2/161) were obese (above +3 SD). Of those that were overweight, 3 were males and 5 were females, whereas both obese infants were male. Seven of the 10 infants who were either overweight or obese were from the L-SES group (Figure F.3, Appendix F).

### 4.1.2.3 HEAD CIRCUMFERENCE

For the infants younger than 6 months (male = 39.6 cm; female = 38.5 cm) and older than 12 months (male = 47.4 cm; female = 46.1 cm), there were significant differences in the mean head circumferences, but none for those between 6 and 12 months (Table 4.2). The significant difference presented between the sexes for the overall cohort (0 – 18 months) may be due to the combined significant differences found in the 0 – 5.9 months and the 12 – 18 months groups that would influence the mean head circumferences of the overall sexes (male = 43.3 cm; female = 42.0 cm) in the study cohort. When the adjusted Bonferroni *p*-value was applied, none of the groups showed any significant differences.

For the 0 – 5.9 months age group, L-SES infants had a smaller head circumference than MU-SES infants (L-SES mean: 38.6 cm vs MU-SES mean: 39.8 cm; $p = 0.024$), specifically L-SES males have a smaller head circumference than MU-SES males ( L-SES mean: 39.2 cm vs MU-SES mean: 41.4 cm; $p = 0.007$) (Table 4.2). These significant differences between the mean head circumferences for the various categories do not translate in significant differences between the mean head circumference-for-age z-scores for the same categories or when the Bonferroni alpha values were applied. Hence, no significant differences were found for either anthropometric measurements or any of the z-score results (Table 4.3).

According to the head circumference-for-age z-score results, approximately 88.8% (143/161) of all infants in this study had a head circumference between -2 and +2 SD from the median (Figure F.4, Appendix F). Of the remainder, 3.1% (5/161; males = 2; females = 3) were between -2 and -3 SD (none were below -3SD), whereas 8.1% (13/161; males = 7; females = 6) were above +2 SD of which one male from the MU-SES group had a z-score of 4.18 SD from the median. Of the 18 infants that did not have a z-score in the normal range, it was evenly split between males and females.

SUMMARY:

In the age group 0 – 5.9 months, females were significantly shorter than males. Length-for-age z-scores also show a significant difference between the SES groups as L-SES males were significantly shorter than MU-SES males specifically in the age group 0 – 5.9 months. No other significant differences based on the normal alpha value (*p*-value) were found for length, and the only Bonferroni significant difference was between the SES groups irrespective of sex. Less than 2 % of infants were stunted, all of whom were from the L-SES group.

The only significant difference for mean weight was for the age group 0 – 5.9 months. Females in this age group weighed less than males, irrespective of SES group (not based on Bonferroni adjusted *p*-value), with none found for any other category. Less than 2 % of infants (only males from L-SES group) were underweight based on weight-for-age z-scores. Approximately 3 % were wasted, but more than 6 % were either overweight or obese.

There were significant differences in mean head circumference between males and females younger than 6 months, and those older than 12 months, but none for those aged between 6 and 12 months. Further results indicate that for those younger than 6 months, there was only a significant difference between males from the different SES groups, but none for the other categories or females. The head circumference-for-age z-scores show no significant differences between any of the categories.

## 4.2 MEDICAL HISTORY AND SOCIO-ECONOMIC INFORMATION OF PARTICIPANTS

Results in this subsection represent the medical history and socio-economic information pertaining to all the successfully recruited participants in this study. The data will be presented as parental/maternal medical history, pre-and post-natal infant medical history, infant feeding data, and socio-economic conditions, as well as the relationships between these variables and age-standardised growth in the children.

### 4.2.1 MEDICAL HISTORY

#### 4.2.1.1 PARENTAL AGE AND MATERNAL MEDICAL HISTORICAL DATA

Maternal ages ranged from 16 to 42 years with a mean of 28 years of age whereas paternal ages ranged from 18 to 62 years with a mean of 31 years (Table 4.4). There were no significant differences in maternal and paternal ages between the SES groups. Both were normally distributed as an overall sample.

**Table 4.4: Descriptive statistics of the parental ages (in years) for all participants for the overall sample of participants, and then for each of the socio-economic status (SES) groups.**

| Sample description | Parental category | N | Mean | SD |
|---|---|---|---|---|
| All recruited parental participants | Maternal age (years) | 161 | 28 | 6 |
| | Paternal age (years) | 158 | 31 | 7 |
| L-SES | Maternal age (years) | 114 | 28 | 6 |
| | Paternal age (years) | 111 | 31 | 7 |
| MU-SES | Maternal age (years) | 47 | 29 | 6 |
| | Paternal age (years) | 47 | 31 | 6 |

**L-SES = Low SES** **MU-SES = Mid-Upper SES**
**N = Number of participants** **SD = standard deviation**

For HIV status, pre-natal and postnatal maternal health-related data per age group per SES group, please refer to Table 4.5. The overall data per SES group for these variables were provided in-text. Of the 161 participants, 96.9% (155/161) of mothers knew their HIV status, and 89.4% (144/161) of mothers knew the HIV status of the fathers. All participants included in the study had a negative HIV status based on clinical records.

A total of 72.1% (116/161) of mothers reported healthy pregnancies, with 28.0% (45/161) reporting one or more health issues (Table 4.5). Of those with health issues, 20.0% (9/45) were diagnosed with gestational diabetes of which two were also diagnosed with hypertension, but no other health issues were reported. A further 17.8% (8/45) were diagnosed with hypertension, and 8.9% (4/45) were diagnosed with a urinary tract infection but had no other health issues. Other health issues such as the common cold and minor infections were reported by the remaining 53.3% (24/45) of mothers. Pearson Chi-Square indicated no significant differences were found between the SES groups concerning these health-related issues.

**Table 4.5: Frequency distribution for maternal health-related information of each participant per age group per socio-economic status (SES) group.**

| | | 0 - 5.9 months | | | 6 - 11.9 months | | | 12 - 18 months | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Category** | **Description** | **MU-SES** | **L-SES** | **Total** | **MU-SES** | **L-SES** | **Total** | **MU-SES** | **L-SES** | **Total** |
| | | **(20)** | **(48)** | **(68)** | **(17)** | **(41)** | **(58)** | **(10)** | **(25)** | **(35)** |
| Gestational health | No pregnancy health issues | 19 | 35 | 54 | 10 | 27 | 37 | 9 | 18 | 27 |
| | Pregnancy health issues | 2 | 14 | 16 | 6 | 15 | 21 | 1 | 7 | 8 |
| Smoking | Non-pregnancy conditions | 7 | 23 | 30 | 8 | 18 | 26 | 2 | 13 | 15 |
| | During pregnancy | 7 | 17 | 24 | 3 | 12 | 15 | 1 | 8 | 9 |
| | While breastfeeding | 7 | 19 | 26 | 4 | 12 | 16 | 1 | 8 | 9 |
| Alcohol consumption | Non-pregnancy conditions | 2 | 13 | 15 | 5 | 16 | 21 | 4 | 13 | 17 |
| | During pregnancy | 0 | 2 | 2 | 0 | 2 | 2 | 0 | 2 | 2 |
| | While breastfeeding | 0 | 2 | 2 | 1 | 0 | 1 | 2 | 2 | 4 |
| HIV/AIDS negative self-reported | Mother | 21 | 48 | 69 | 15 | 41 | 56 | 10 | 22 | 32 |
| | Father | 21 | 43 | 64 | 15 | 38 | 53 | 9 | 20 | 29 |

**Months = months of age MU-SES = Mid-to-Upper SES L-SES = Low-SES**

Approximately 44.1% (71/161) of mothers reported that they smoked when not pregnant, of which 25.4% (18/71) were from the MU-SES group, and 74.6% (53/71) were from the L-SES group (Table 4.5). Maternal smoking during pregnancy was approximately 67.6% (48/71) of the total number of smoking mothers (MU-SES = 12; L-SES = 36; Table 4.5). The reported average number of cigarettes smoked during pregnancy was 3 per day (ranging from 1 to 5 per day), which was less than half the consumption when not pregnant (average of 10, ranging 6-15 per day). Approximately 71.8% (51/71) of smoking mothers reported that they smoked during the breastfeeding period (MU-SES = 12; L-SES = 39; Table 4.5), though not while breastfeeding or within the same environment where the infant was. Pearson Chi-Square showed no significant difference between the SES groups for mothers who smoked during pregnancy or during the breastfeeding period.

Most mothers (68%; 109/161) stated that they did not consume alcohol (Table 4.5). Of those who consumed alcohol during non-pregnancy periods, 21.2% (11/52) were in the MU-SES group and 78.8% (41/52) in the L-SES group. None of the MU-SES group consumed alcohol during pregnancy or during the breastfeeding period (Table 4.5). In the L-SES group, 14.6 % (6/41; or 11.5% of 52) reported consumption during pregnancy and 17.1% (7/41; or 13.5% of 52) reported consumption during the breastfeeding period though not while breastfeeding or shortly before breastfeeding (Table 4.5). Pearson Chi-Square showed no significant difference for mothers who consumed alcohol during pregnancy between the SES groups, and no significant difference between the SES groups for mothers who consumed alcohol during the breastfeeding period.

Eta coefficients showed no association between maternal educational years (results reported below in subsection 4.2.2.2), and maternal smoking or drinking during pregnancy, but maternal age had weak associations with both these variables (Eta values = 0.395 and 0.419, respectively). If the sample cohort had more mothers smoking and drinking during pregnancy, some of these associations might have been stronger.

#### 4.2.1.2 INFANT MEDICAL HISTORICAL DATA

All 161 infants had all the required immunisations for their age in accordance with the recommendations by the South African National Department of Health (NDoH) as set out in the Road-to-Health booklet, and all those older than 6 months (93) had taken deworming tablets and vitamin booster drops as recommended and provided by the NDoH.

The mean gestational age for all (161) participating infants was 39.3 weeks; a mean of 39.0 weeks (SD = 1.3 weeks) for the MU-SES group and 39.4 weeks (SD = 1.7 weeks) for the L-SES group. Comparing mean gestational age between the SES groups indicated no significant difference. Approximately 88.8% (143/161) of infants were reported to have a healthy weight at birth (within acceptable range based on gestational age). Mothers who reported this healthy weight status during the interview process, said that they were informed by the medical professionals who assisted during and after the birthing process. Approximately 11.2% (18/161) of infants were reported as underweight at birth (MU-SES = 4 or 8.5% of 47; L-SES = 14 or 12.3% of 114). Pearson Chi-Square indicated no significant difference between the SES groups regarding healthy weight at birth. Neither maternal smoking nor drinking during pregnancy were associated with gestational age based on Eta values, and Pearson Chi-

Square tests showed no significant differences for weight at birth in association with either of these variables.

The frequency distribution for infants who were breastfed fully or partially are represented in Table 4.6 with information subdivided into SES and age groups. Nearly half of all infants (49.7% or 80/161) in the study cohort were exclusively breastfed, 19.9% (32/161) were exclusively formula fed, and 30.4% (49/161) were breast- and formula fed, prior to the introduction of solid food products (Table 4.6). In the age group 0 – 5.9 months the average exclusive breastfeeding duration was 2.0 months for the MU-SES group and 1.6 months for the L-SES group. In the age group 6 – 11.9 months the average exclusive breastfeeding duration was 3.1 months for the MU-SES group and 3.6 months for the L-SES group whereas for the age group 12 – 18 months, it was 4.1 and 4.3 months, respectively. There were no significant differences for exclusive breastfeeding duration between the SES groups for any of the age groups based on an ANOVA test, and a Cramer's V test indicated no significant difference of feeding method between the SES groups. Eta values of 0.17 to 0.03, indicated no association in exclusive breastfeeding duration between the SES groups for each of the age groups.

**Table 4.6: Frequencies per socio-economic status (SES) group representing the number of infants that were breastfed and the mean duration of exclusive breastfeeding.**

| SES group | Age group | N | Number of Infants | | | | Mean exclusive breastfeeding duration (months) | |
|---|---|---|---|---|---|---|---|---|
| | | | Breastfed& Formula fed | | Exclusively breastfed | | Mean | SD |
| Mid-Upper SES | 0 - 5.9 months | 20 | 8 | 40.0% | 9 | 45.0% | 2.0 | 1.3 |
| | 6 - 11.9 months | 17 | 8 | 47.1% | 6 | 35.3% | 3.1 | 2.1 |
| | 12 - 18 months | 10 | 0 | 0.0% | 7 | 70.0% | 4.1 | 3.1 |
| Low-SES | 0 - 5.9 months | 48 | 9 | 18.8% | 30 | 62.5% | 1.6 | 0.9 |
| | 6 - 11.9 months | 41 | 16 | 39.0% | 16 | 39.0% | 3.6 | 2.3 |
| | 12 - 18 months | 25 | 8 | 32.0% | 12 | 60.0% | 4.3 | 2.8 |

**N = Number of participants**

In addition to milk products, solid food products such as mashed vegetables are recommended to be introduced from 6 months onwards, and internationally referred to as complementary foods. Most of the infants (98.8% or 159/161) younger than 6 months were breastfed and/or formula fed, except for two infants (1 in the MU-SES group at 3 months; and 1 in the L-SES group at 1 months) who had complementary foods introduced prior to 6 months.

Except for these two cases, there were no significant difference between the SES groups concerning the age in months for the introduction of complementary foods (Table 4.7). The average age of participating infants older than 6 months started consuming solid food products from 5.5 months (MU-SES = 5.8 months; L-SES = 5.3 months) (Table 4.7). An Eta directional measure of 0.081 also showed no association, and neither did an ANOVA.

**Table 4.7: Descriptive statistics per socio-economic status (SES) group for all infants aged 6 – 18 months that have started complementary (solid) foods, and those that mainly consume solid food.**

| SES group | Age | Total | Start complementary (solid) foods | | | Mainly consume solid food | | |
|---|---|---|---|---|---|---|---|---|
| | | | N | Mean | SD | N | Mean | SD |
| Mid-Upper SES | 6 – 18 months | 26 | 26 | 5.8 months | 1.3 | 16 | 8.7 months | 2.3 |
| Low SES | 6 – 18 months | 67 | 67 | 5.3 months | 1.2 | 19 | 8.5 months | 2.9 |

**N = Number of participants** **SD = Standard deviation**

In the age range 6 – 18 months, approximately 37.6% (35/93) of infants consumed more solids than breast- and/or formula milk. The average age when more solid food products than breast- and/or formula milk were consumed by infants in the study cohort was 8.5 months. An ANOVA indicated that there was a significant difference ($p$ = 0.016) in the mean age when more solid food was consumed compared to milk products between the SES groups, but an Eta directional measure value of 0.189 showed nearly no association.

Past health issues for all infants are presented in Table 4.8. More than double the percentage of L-SES infants (57.9% or 66/114) suffered bacterial infections than MU-SES infants (25.5% or 12/47). Bacterial infections were significantly different ($p$ = 0.041) between the SES groups, especially nasal infections (that are bacteria-related) showed a significant difference ($p$ = 0.002) between the SES groups, and when the Bonferroni alpha value of 0.005 was applied, the SES group difference remained significant. The percentage viral infections in the MU-SES group infants (17.0% or 8/47) were slightly higher than the L-SES infants (14.9% or 17/114) but was not significantly different between the SES groups. All infants who were diagnosed with jaundice, were diagnosed within the first week after birth, and medically treated in hospital by exposure to ultraviolet light. Dermatological issues were nearly four times higher in the L-SES group (7.9% or 9/114) than in the MU-SES group (2.1% or 1/47), yet a Pearson Chi-Square test showed no significant difference between the SES groups.

Infant health issues were cross tabulated with maternal smoking and drinking during pregnancy and/or the breastfeeding period. Most cross tabulations were not significant except for chest infections and jaundice. Chest infections had a significant association ($p = 0.004$) with maternal drinking during the breastfeeding period and remained significant when the Bonferroni alpha value ($p \leq 0.005$) was applied. Jaundice significantly associated ($p = 0.014$) with maternal drinking during pregnancy but did not remain significant based on the Bonferroni alpha value.

**Table 4.8: Frequency distribution of infant illnesses per age group per SES group, and the total percentage for the full infant cohort (0 – 18 months).**

| Illness | 0 - 5.9 months | | | 6 - 11.9 months | | | 12- 18 months | | | 0 – 18 months |
|---|---|---|---|---|---|---|---|---|---|---|
| | MU-SES | L-SES | Overall | MU-SES | L-SES | Overall | MU-SES | L-SES | Overall | Total |
| | N | N | % | N | N | % | N | N | % | % |
| | 20 | 48 | | 17 | 41 | | 10 | 25 | | |
| Bacterial infection | 1 | 14 | 22.1 | 6 | 31 | 53.4 | 5 | 21 | 74.3 | 48.4 |
| Viral infections | 2 | 4 | 8.8 | 5 | 4 | 15.5 | 1 | 9 | 28.6 | 15.5 |
| Jaundice | 0 | 4 | 5.9 | 1 | 3 | 6.9 | 0 | 4 | 11.4 | 7.5 |
| Dermatological issues | 0 | 5 | 7.4 | 1 | 4 | 8.6 | 0 | 0 | 0 | 6.2 |

**MU-SES = Mid-upper SES L-SES = Low SES N = number of participants % = percentage**

Based on all the parental age, maternal and infantile medical history data, measures of association were calculated for the various continuous, ordinal and/or nominal data. This included measures of association between the four different z-scores and the data from the questionnaires, and between the various data from the questionnaires. Bonferroni significant differences were indicated with a '**B**' next to the *p*-values as shown at the bottom of Table 4.9.

Both maternal age and paternal age had significant Pearson's *r* correlations with either all the z-scores or three of the z-scores, respectively (Table 4.9), yet only the weight-for-age z-score had a significant Bonferroni *p*-value for both maternal and paternal age. Maternal smoking and drinking during pregnancy and during the breastfeeding period had either very weak or no association with all z-scores based on directional measure of the Eta value, with the highest being 0.164 for the effect maternal smoking during pregnancy has on length-for-age z-score. Similarly, maternal health issues also had very weak to no association with all z-scores based on Eta directional measurement values, with the highest Eta value of 0.199 for the hypertension had on weight-for-age z-score.

**Table 4.9: Pearson product-moment correlation coefficient (*r*) analyses of each z-score associated with various continuous explanatory variables, irrespective of socio-economic status (SES) group.**

| Explanatory variable | zlen | | zwei | | zwfl | | zhc | |
|---|---|---|---|---|---|---|---|---|
| | *r* | *p* | *r* | *p* | *r* | *p* | *r* | *p* |
| Maternal age (years) | **0.169*** | 0.032 | **0.245**** | **0.002[B]** | **0.177*** | 0.025 | **0.213**** | **0.007[B]** |
| Paternal age (years) | 0.092 | 0.250 | **0.209**** | **0.008[B]** | **0.171*** | 0.031 | **0.178*** | 0.025 |
| | | | | | | | | |
| Gestational age (weeks) | **0.220**** | **0.005[B]** | **0.177*** | 0.025 | 0.029 | 0.712 | **0.236**** | **0.003[B]** |
| Exclusive breastfeeding duration (months) | **0.161*** | 0.041 | **0.185*** | 0.019 | 0.129 | 0.104 | **0.255**** | **0.001[B]** |
| Infant age when solid (complementary) food products introduced into infant diet | **0.205**** | 0.009 | **0.225**** | **0.004[B]** | 0.131 | 0.098 | **0.200*** | 0.011 |
| Infant age when infant diet contains more solid food products than milk products | 0.013 | 0.875 | **0.158*** | 0.045 | **0.177*** | 0.025 | **0.164*** | 0.038 |

zlen = length-for-age z-score
zwei = weight-for-age z-score
zwfl = weight-for-length-for-age z-score
zhc = head circumference-for-age z-score
*r* = Pearson's *r* coefficient
*p* = two-tailed significant factor
*****. Correlation is significant at the 0.05 level (2-tailed)
******. Correlation is significant at the 0.01 level (2-tailed)
Bonferroni: ***p*≤0.008[B]** indicates significant difference.

Gestational age, exclusive breastfeeding duration and the age when complementary foods were introduced had significant correlations with length-, weight- and head circumference-for-age z-scores (Table 4.9). The infant age when more solid food was consumed than milk products were significantly associated with weight-, weight-for-length- and head circumference-for-age but based on the Bonferroni concept (calculated at $p = 0.008$) these significant difference were nulled (Table 4.9). Weight at birth (indicated as status at birth on the questionnaire) also had weak associations with length-, weight-, weight-for-length- and head circumference-for-age z-scores with Eta values ranging from 0.127 to 0.232. Infantile health issues had no association with the z-scores.

### 4.2.2 SOCIO-ECONOMIC DATA

4.2.2.1 RESIDENTIAL HOUSEHOLD DATA

On average, three in four (75.2% or 121/161) participants lived with parents and/or siblings, grandparents and/or cousins although this was much higher within the L-SES group (81.6% or 93/114) than in the MU-SES group (59.6% or 28/47). The percentage of those who owned or rented property was more than double in the MU-SES group (owned = 17.0%, rented = 23.4%) than in the L-SES group (owned = 7.9%, rented = 10.5%) (Table 4.10). There was a significant difference ($p = 0.004$) in the type of residence (own, rent or staying with family) between the SES groups based on an independent-samples Mann-Whitney U test. Overall (both SES groups), 88.8% (143/161) of mothers have 1 to 3 dependents. A crosstabulation between SES group and number of maternal dependents resulted in an Eta value of 0.149 that indicated a very weak association between the variables, and a Mann-Whitney U test showed no significant difference between the SES groups for number of maternal dependents. The Eta association might have been due to the frequency of mothers who had either one dependent (in the MU-SES group 51.1% (24/47) of mothers and in the L-SES group 36.0% (41/114) mothers), or three dependents (in the MU-SES group 14.9% (7/47) of mothers and in the L-SES group 23.9% (27/114) mothers). The other frequencies were fairly evenly distributed.

**Table 4.10: Frequency distribution of living environment per age group per socio-economic status (SES) group, and the total percentage for full infant cohort (0 – 18 months).**

| Living environment | 0 - 5.9 months | | | 6 - 11.9 months | | | 12- 18 months | | | 0 – 18 months |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mu-SES | L-SES | Overall % | Mu-SES | L-SES | Overall % | Mu-SES | L-SES | Overall % | Total % |
| | Frequency (N) | | | Frequency (N) | | | Frequency (N) | | | |
| | 20 | 48 | | 17 | 41 | | 10 | 25 | | |
| Own property | 4 | 6 | 14.7% | 2 | 3 | 8.6% | 2 | 0 | 5.7% | 10.5% |
| Rental property | 4 | 5 | 13.2% | 5 | 5 | 17.2% | 2 | 2 | 11.4% | 14.3% |
| Stay with family | 12 | 37 | 72.1% | 10 | 33 | 74.1% | 6 | 23 | 82.9% | 75.2% |
| Internal house water source | 20 | 41 | 89.7% | 17 | 35 | 89.7% | 10 | 22 | 91.4% | 90.1% |
| External house water source | 0 | 7 | 10.3% | 0 | 6 | 10.3% | 0 | 3 | 8.6% | 9.9% |
| Internal house sanitation | 20 | 36 | 82.4% | 17 | 31 | 82.8% | 10 | 21 | 88.6% | 83.9% |
| External house sanitation | 0 | 12 | 17.6% | 0 | 10 | 17.2% | 0 | 4 | 11.4% | 16.1% |

**months = months of age** **MU-SES = Mid-upper SES group** **L-SES = Low SES group**
**N = number of participants** **% = percentage**

None of the MU-SES group's participants had to use external (outside of the residential structure) water sources or sanitation facilities. In the L-SES group, 14.0% (16/114) of participants used an external water source and approximately 22.8% (26/114) participants in this group used external sanitation (Table 4.10). Both water source ($p$ = 0.007) and sanitation ($p$ = 0.000) were significantly different between the SES groups for the overall number of participants in each SES group based on Chi-Square crosstabulation tests.

Household occupancy (number of adults and children within a household) averaged 5 individuals in the MU-SES group, and 7 individuals in the L-SES group (Table 4.11). In this data set, housing densities of 20 and 21 individuals (L-SES group) were considered outliers. If these outliers were removed, the range in household occupancy per L-SES household changed to 3 – 9 individuals although it did not significantly change the average. Average household occupancy in the MU-SES group consisted of 3 adults, and 2 children younger than 18 years of age whereas it was 4 adults, and 3 children in the L-SES group (Table 4.11). An Eta value of 0.233 indicated a very weak association between household occupancy and SES group, whereas a significant difference was found based on a Kruskal-Wallace independent-sample distribution test between the household occupancy for the SES groups. Interestingly, there was no significant difference for the number of adult residents in a household when the SES groups were compared, but there was one for the number of children in residence.

**Table 4.11: Descriptive statistics for the number of children, adults, and household density in residence per socio-economic status (SES) group.**

| Category Description | MU-SES group | | L-SES group | | Eta value | *p* |
|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | | |
| No. of children in household | 2 | 0.9 | 3 | 1.5 | 0.327 | **0.000*** |
| No. of Adults in household | 3 | 1.5 | 4 | 2.1 | 0.097 | 0.225 |
| Household occupancy | 5 | 1.9 | 7 | 3.0 | 0.233 | **0.003*** |

**No. = number** **MU-SES = Mid-to-Upper SES** **L-SES = Low SES**

***p*≤0.05*indicates significant difference** **SD = standard deviation**

### 4.2.2.2 MATERNAL EDUCATION AND HOUSEHOLD FINANCE DATA

Maternal education, in terms of completed years in a formal education system, the L-SES group had an average of 10.8 years of completed formal education with 80% of all mothers in this group who exited formal education between grades 8 and 12 (Table 4.12). In the MU-SES group, the average was 13.0 years with 60% of mothers who had more than 12 years of formal education. The percentage of mothers with 12 years of formal education with additional external practical courses (to the schooling system) to perform work-related duties were 36.2% (17/47) in the MU-SES group and 23.7% (27/114) in the L-SES group. MU-SES mothers were seven times (31.9% or 15/47) more likely to be high-school (grade 12 or senior year) or tertiary graduates compared to L-SES mothers (4.4% or 5/114). Based on the study data, there was a Pearson Chi-Square significant difference in mean maternal educational years between the two SES groups with an Eta value of 0.502 that suggested a moderate association (Table 4.12).

**Table 4.12: Descriptive statistics for the number of children, adults, and household density in residence per socio-economic status (SES) group.**

| Category Description | MU-SES group | | L-SES group | | Eta value | *p* |
|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | | |
| Maternal education (years) | 13.0 | 1.5 | 10.8 | 1.8 | 0.502 | **0.000*** |
| Maternal number of dependents | 1.8 | 1.0 | 2.2 | 1.1 | 0.149 | 0.320 |

**No. = number** **MU-SES = Mid-to-Upper SES** **L-SES = Low SES**

***p*≤0.05*indicates significant difference** **SD = standard deviation**

In the MU-SES group 66.0% of mothers were employed compared to 38.6% of mothers in the L-SES group (Table 4.13). In the L-SES group, 24.6% (28/114) mothers were financially dependent on another employed individual in the household that is not a parent to their child(ren) compared to 17.0% (8/47) of mothers in the MU-SES group. In the L-SES group, 10.5% (12/114) of households had no official source of income, even on an irregular basis, and was mainly reliant on the South African child grant as provided by the government. Chi-Square tests for both maternal employment and general household income showed significant differences between the SES groups (Table 4.13). Interestingly, unemployment appeared to be slightly higher in the MU-SES group (19.1% or 9/47) compared to the L-SES group (14.9% or 17/114) but considering 3 of the 9 MU-SES mothers are students, this had a noticeable impact on the percentage of those unemployed in the MU-SES group (12.8% or 6/47). More individuals were permanently employed in the MU-SES group (66.0% or 31/47) than in the L-SES group (57.9% or 66/114). None of the L-SES group's employed individuals earned an annual salary above ZAR 350 000.00 (South African Rand) or 22 750 USD (Table 4.13). Nearly double the number of MU-SES employed mothers who participated earned between ZAR 80 000.00 – 350 000.00 (5 200 – 22 750 USD) compared to those in the L-SES. Nearly a fifth of L-SES mothers did not know what the household income was, if any.

**Table 4.13: Frequency and percentages for maternal employment and household salary scale per socio-economic status (SES) group.**

| **Categorical variable** | | **MU-SES group** | | **L-SES group** | | ***p*** |
|---|---|---|---|---|---|---|
| | | **N (47)** | **%** | **N (114)** | **%** | |
| Does the mother work? | Yes | 31 | 66.0 | 44 | 38.6 | **0.004*** |
| | No | 16 | 34.0 | 59 | 51.8 | |
| Salary scale | < R80 000 | 12 | 25.5 | 59 | 51.8 | **0.000*** |
| | R 80 000 - R 350 000 | 28 | 59.6 | 33 | 28.9 | |
| | > R 350 000 | 5 | 10.6 | 0 | 0.0 | |
| | Unknown | 2 | 4.3 | 22 | 19.3 | |

***p*≤0.05*indicates significant difference** **N = number of participants** **% = percentage**

**MU-SES = Mid-to-Upper SES** **L-SES = Low SES**

In terms of medical care cost (private, government-funded or both), more than 90% (43/47) of mothers from the MU-SES group stated that they used private medical care when their children needed medical attention (excluding immunisations) compared 33.3% (38/114) in the L-SES group (Table 4.14). Nearly two thirds (62.3% or 71/114) of mothers in the L-SES group only used the free government health care facilities, with less than 5% (5/114) who used both private and government health care facilities depending on the nature of the infant's need of a primary health care professional. A Pearson Chi-Square indicated a significant difference between the SES groups (Table 4.14).

**Table 4.14: Frequency and percentages for medical care cost per socio-economic status (SES) group.**

| **Medical care cost** | **0 – 18 months of age** | | | | ***p*** |
|---|---|---|---|---|---|
| | MU-SES | | L-SES | | |
| | **N** | **%** | **N** | **%** | |
| Private medical care | 43 | 91.5 | 38 | 33.3 | **0.000*** |
| Government funded care | 1 | 2.1 | 71 | 62.3 | |
| Private + Government care | 3 | 6.4 | 5 | 4.4 | |

***p*≤0.05*indicates significant difference**

**MU-SES = Mid-to-Upper SES** **L-SES = Low SES** **N = frequency** **% = percentage**

Measures of association were performed for the socio-economic data that consisted of residential household, maternal education and household finance data compared to all the z-scores (Table 4.15). For continuous-continuous data such as maternal education, number of dependents and household occupancy variables versus the z-scores a Pearson product-moment correlation coefficient (*r*) was determined, whereas a Spearman rank correlation coefficient ($r_S$) was used to determine associations between continuous-ordinal data such as salary scale and medical care cost versus the z-scores. An Eta coefficient test and a Mann-Whitney U test were used to measure the degree of association between the nominal data versus the continuous data of the z-scores. All statistical results were presented in Table 4.15.

**Table 4.15: Measures of association analysing each z-score associated with various explanatory variables, irrespective of socio-economic status (SES) group.**

| Explanatory variable | zlen | | zwei | | zwfl | | zhc | |
|---|---|---|---|---|---|---|---|---|
| **Pearson product-moment correlation coefficient** | ***r*** | ***p*** | ***r*** | ***p*** | ***r*** | ***p*** | ***r*** | ***p*** |
| Maternal education (years) | **0.295**** | **0.000**[B] | **0.205**** | 0.009 | 0.008 | 0.920 | **0.189*** | 0.016 |
| Household occupancy | 0.093 | 0.244 | **0.171*** | 0.031 | **0.210**** | **0.008**[B] | 0.119 | 0.133 |
| Number of dependents of mother | -0.019 | 0.810 | 0.142 | 0.072 | **0.216**** | **0.006**[B] | 0.075 | 0.346 |
| **Spearman rank correlation coefficient** | $r_S$ | ***p*** | $r_S$ | ***p*** | $r_S$ | ***p*** | $r_S$ | ***p*** |
| Salary scale | **0.159*** | 0.045 | 0.018 | 0.821 | **-0.163*** | 0.040 | -0.005 | 0.950 |
| Medical care cost | 0.121 | 0.126 | 0.090 | 0.258 | -0.005 | 0.952 | 0.005 | 0.945 |
| **Mann-Whitney U test** | Eta value | ***p*** | Eta value | ***p*** | Eta value | ***p*** | Eta value | ***p*** |
| Does the mother work? | 0.086 | 0.489 | 0.013 | 0.658 | 0.061 | 0.489 | 0.064 | 0.364 |

zlen = length-for-age z-score
zwei = weight-for-age z-score
zwfl = weight-for-length-for-age z-score
zhc = head circumference-for-age z-score
*r* = Pearson's *r* coefficient
$r_S$ = Spearman rho coefficient
*p* = two-tailed significant factor
Bonferroni: ***p*≤0.008**[B] indicates significant difference.
*. Correlation is significant at the 0.05 level (2-tailed)
**. Correlation is significant at the 0.01 level (2-tailed)

For all but three residential household variables, all measures of association showed no correlation with any of the z-scores. Household occupancy (adults + children) was significantly correlated to two of the z-score, *i.e.* with weight- and weight-for-length-for age, but only weight-for-age remained significant based on the Bonferroni *p*-value of 0.008.

It was found that maternal education correlated significantly with length-, weight- and head circumference-for-age z-scores, when a normal alpha value of 0.050 was used. Using the

Bonferroni adjusted alpha value of 0.008, only length-for-age z-scores remained significant (Table 4.15). In the L-SES group, maternal education (years) showed a significant (*p* = 0.013 to 0.001) positive correlation coefficient with length-, weight- and head circumference-for-age z-scores (the same as the overall study cohort), but none for weight-for-length-for-age. It is the inverse for the MU-SES group. No significant correlations were found with length-, weight- and head circumference-for-age, but a significant (*p* = 0.028) negative correlation coefficient resulted for the weight-for-length-for-age z-score. Using the Bonferroni *p*-value only the weight-for-age z-scores remained significantly correlated with maternal education in the L-SES group.

Significant correlations were found between salary scale and length- and weight-for-length-for-age z-scores, but neither remained significant based on the Bonferroni *p*-value (Table 4.15). The only significant correlation (*p* = 0.039) of salary scale was in the L-SES group for weight-for-length-for-age and it was negative (*r* = -0.195). None of the z-scores showed a significant correlation with medical care cost, nor did Eta values show any association for the nominal variable 'Does the mother work?'.

### 4.2.3 FOOD SECURITY AND AVAILABILITY

The food security questionnaire results were presented as (i) concern regarding adequate food quantity for household, (ii) the availability and variety of preferred food choices, and (iii) reduced meal portions or lack of food at various mealtimes, over the 4 weeks prior to completing the questionnaire as is stated in the pre-set questions of the HFIAS questionnaire (Figure E.2, Appendix E).

In the MU-SES group 78.7% (37/47) of mothers stated that they had no concerns regarding food availability for all household members whereas 57.9% (66/114) of mothers in the L-SES group stated the same. In the MU-SES group, it was reported that 83% (39/47) of the participating households could obtain their preferred food choices compared to 57.0% (65/114) in the L-SES group. More than double the number of mothers in the L-SES group (48.3% or 55/114) stated that they had a limited variety of food choices based on their available financial resources compared to mothers in the MU-SES group (21.3% or 10/47).

Frequency distribution statistics showed that 40.4% (46/114) of mothers in the L-SES group stated that they had smaller meals (HFIAS question 'e.', Figure E.2, Appendix E) than they felt would be adequate compared to 14.9% (7/47) in the MU-SES group. Furthermore, 28.3% (13/46) of the L-SES group stated that having smaller meals occurred 'often (more than

10 times)' in the four weeks prior to the survey. L-SES group mothers who stated that they had fewer meals (less than three meals) per day (HFIAS question 'f.', Figure E.2, Appendix E) accounted for 29.8% (34/114) of the total in this SES group compared to 12.8% (6/47) in the MU-SES group. Thirteen (13) of the 34 L-SES group mothers stated that this also occurred 'often (more than 10 times)' in the four weeks prior to the survey. Furthermore, 14.0% (16/114) of mothers in the L-SES groups stated that there was no food available in the household due to a lack of financial resources (HFIAS question 'g.', Figure E.2, Appendix E) compared to 4.3% (2/47) of mothers in the MU-SES group. Of the 16 mothers from the L-SES group who stated there was no food available, 13 stated this occurred 'sometimes (3 to 10 times)' or 'often (more than 10 times)' in the four weeks prior to the survey. None of the MU-SES group went to sleep without a meal or went without a meal in a 24-hour period.

Independent-sample mean tests showed that most of the Household Food Insecurity Access Scale (HFIAS) question were significantly different between the two SES groups, specifically regarding food availability, limited variety of food, smaller meals and fewer meals per day were different between these two groups (Table 4.16). Interestingly though the results for the HFIAS questions 'h.' and 'i.' showed that there was no difference (null hypothesis retained) in the distribution of responses between the SES groups. This might have been due to the fact that although none of the mothers from the MU-SES group responded 'Yes' to these questions, the percentage of L-SES group mothers who responded 'Yes' was less than 8.0% for these questions.

**Table 4.16: Independent-samples median test results for all the Household Food Insecurity Access Scale (HFIAS) questions between the mid-upper socio-economic status (SES) group and the low SES group.**

| HFIAS question | Independent-Samples Median Test: Null Hypothesis | *p* | Retain/Reject null hypothesis |
|---|---|---|---|
| a. | The medians of Worry about food availability are the same across categories of SES groups. | **0.020** | $H_1$ |
| b. | The medians of Unable to eat preferred foods are the same across categories of SES groups. | **0.003**[B] | $H_1$ |
| c. | The medians of Eat just a few kinds of foods are the same across categories of SES groups. | **0.003**[B] | $H_1$ |
| d. | The medians of Eat foods they really do not want eat are the same across categories of SES groups. | **0.010** | $H_1$ |
| e. | The medians of Eat a smaller meal than needed are the same across categories of SES groups. | **0.003**[B] | $H_1$ |
| f. | The medians of Eat fewer meals in a day than needed are the same across categories of SES groups. | **0.038** | $H_1$ |
| g. | The medians of No food of any kind in the household are the same across categories of SES groups. | 0.130 | $H_0$ |
| h. | The medians of Go to sleep hungry are the same across categories of SES groups. | 0.108 | $H_0$ |
| i. | The medians of Go a whole day and night without eating are the same across categories of SES groups. | 0.252 | $H_0$ |

***p*≤0.05*indicates asymptotic significant difference** Bonferroni: ***p*≤0.006**[B] indicates significant difference.

HFIAS = Household Food Insecurity Access Scale SES = Socio-economic status

$H_0$ = Retain the null hypothesis
$H_1$ = Reject the null hypothesis

The total food availability score (27) was significantly different ($p$ = 0.000) between the two SES groups and had a negative Spearman rank correlation coefficient ($r_s$) of -0.329 based on the coding for the SES groups with '1' identifying the L-SES group and '2' the MU-SES group. This HFIAS total score was not significantly correlated to any of the z-scores. Though the following was not part of the food security and availability questionnaire, the few mothers who indicated that there were times when they went to sleep hungry stated that they made sure all their children were provided with some form of food.

### 4.2.4 COLLINEAR AND PROXY VARIABLES

This subsection of the results dealt with all the explanatory variables from the questionnaires that had significant correlations or measures of association with the z-scores as some would have been possible proxies or collinear with other variables. In preparation for the results of the multivariate regression models, it was important to determine which variables would be best to use for the analyses. All explanatory variables that significantly associated with each of the z-scores, *i.e*. length-for-age, weight-for-age, weight-for-length-for-age and head circumference-for-age, were given, and then those that were either proxy or collinear variables were presented. Results from this subsection were instrumental for the multivariate regression analyses reported in the next section.

The length-for-age z-score was significantly associated with maternal age, gestational age, exclusive breastfeeding duration, infant age when complementary food was introduced (all from Table 4.9), maternal education, salary scale and weight at birth (both from Table 4.15). Most of these variables were not collinear based on the collinear diagnostics that were performed (Table 4.17). A variance inflation factor (VIF) greater than 3.0 would have indicated weak collinearity whereas a VIF greater than 10 would have indicated strong collinearity between variables. An Eta value of 0.527 was determined for weight at birth (normal or not normal) when associated with gestational age, thus was viewed as a proxy for gestational age. Therefore, these two variables could not be used in the same multivariate regression model. Both were used for the statistical analysis, but the better result was presented. Exclusive breastfeeding duration was significantly correlated with infant age when complementary (solid) food was introduced (Tables 4.19), which also made them proxy variables as they were not collinear on the basis of the VIF.

**Table 4.17: Variance inflation factors (VIF) to determine collinearity between explanatory variables. Abbreviations (Abbrev.) were given for each variable then used as headings in the first row.**

| Explanatory variable description | Abbrev. | Collinearity coefficients: Variance inflation factors (VIF) | | | | | |
|---|---|---|---|---|---|---|---|
| | | **MA** | **ME** | **HD** | **MD** | **ExB** | **AS** |
| Maternal age (years) | MA | | 2.6 | 2.8 | 2.6 | 2.9 | 2.9 |
| Paternal age (years) | PA | 1.0 | 2.5 | 2.4 | 2.5 | 2.6 | 2.6 |
| Maternal education (years) | ME | 1.1 | | 1.1 | 1.1 | 1.2 | 1.2 |
| Household occupancy | HD | 1.1 | 1.2 | | 1.2 | 1.2 | 1.2 |
| Number of maternal dependents | MD | 1.6 | 1.7 | 1.7 | | 1.8 | 1.8 |
| Gestational age (weeks) | GA | 1.1 | 1.1 | 1.1 | 1.1 | 1.0 | 1.1 |
| Exclusive breastfeeding duration (months) | ExB | 1.4 | 1.4 | 1.4 | 1.4 | | 1.1 |
| Infant age when solid (complementary) food products introduced into infant diet | AS | 1.6 | 1.6 | 1.6 | 1.6 | 1.2 | |
| Infant age when infant diet contains more solid food products than milk products | S>M | 1.2 | 1.2 | 1.2 | 1.2 | 1.8 | 1.8 |

**Table 4.18: Pearson product-moment correlation coefficient (*r*) analyses of maternal age (years), maternal education (years), and household occupancy associated with various continuous explanatory variables, irrespective of socio-economic status (SES) group.**

| Explanatory variable | Maternal Age (years) | | Maternal education (years) | | Household occupancy | |
|---|---|---|---|---|---|---|
| | ***r*** | ***p*** | ***r*** | ***p*** | ***r*** | ***p*** |
| Maternal age (years) | | | 0.062 | 0.435 | 0.170* | 0.032 |
| Paternal age (years) | 0.748** | **0.000**[B] | -0.058 | 0.467 | 0.025 | 0.755 |
| Maternal education (years) | 0.062 | 0.435 | | | -0.235** | **0.003**[B] |
| | | | | | | |
| Number of adults living in household | 0.113 | 0.154 | -0.181* | 0.022 | | |
| Number of children living in household | 0.168* | **0.003**[B] | -0.233** | **0.003**[B] | | |
| Number of dependents of mother | 0.593** | **0.000**[B] | -0.185* | 0.019 | 0.294** | **0.000**[B] |

*r* = Pearson's *r* coefficient

*****. Correlation is significant at the 0.05 level (2-tailed)

******. Correlation is significant at the 0.01 level (2-tailed)

*p* = two-tailed significant factor

Bonferroni: **p≤0.008**[B] indicates significant difference.

**Table 4.19: Pearson product-moment correlation coefficient (*r*) analyses of maternal age (years), maternal education (years), gestational age (weeks) and exclusive breastfeeding duration (months) correlated with other maternal and infant continuous explanatory variables.**

| Explanatory variable | Maternal age (years) | | Maternal education (years) | | Exclusive breastfeeding duration (months) | |
|---|---|---|---|---|---|---|
| | ***r*** | ***p*** | ***r*** | ***p*** | ***r*** | ***p*** |
| Maternal age (years) | | | 0.062 | 0.435 | -0.014 | 0.863 |
| Maternal education (years) | 0.062 | 0.435 | | | -0.017 | 0.828 |
| Maternal number of dependents | 0.593** | **0.000[B]** | -0.185* | 0.019 | 0.025 | 0.757 |
| Household occupancy | 0.170* | 0.032 | -0.235** | 0.003 | 0.089 | 0.262 |
| | | | | | | |
| Infant age (months) | -0.053 | 0.501 | -0.043 | 0.585 | 0.471** | 0.000 |
| Gestational age (weeks) | 0.002 | 0.978 | -0.030 | 0.701 | 0.197* | 0.012 |
| Infant age when solid (complementary) food products introduced into infant diet | -0.060 | 0.452 | -0.017 | 0.832 | 0.514** | **0.000[B]** |
| Infant age when infant diet contains more solid food products than milk products | -0.051 | 0.519 | 0.039 | 0.627 | 0.207** | 0.009 |

*r* = Pearson's *r* coefficient
*. Correlation is significant at the 0.05 level (2-tailed)
**. Correlation is significant at the 0.01 level (2-tailed)

*p* = two-tailed significant factor
Bonferroni: **p≤0.006[B]** indicates significant difference.

**Table 4.20: Spearman rank correlation coefficient ($r_S$) analyses of maternal age (years), maternal education (years), and household occupancy associated with various ordinal explanatory variables, irrespective of socio-economic status (SES) group.**

| Explanatory variable | Maternal age (years) | | Maternal education (years) | | Number of dependents of mother | | Household occupancy | |
|---|---|---|---|---|---|---|---|---|
| | $r_S$ | ***p*** | $r_S$ | ***p*** | $r_S$ | ***p*** | $r_S$ | ***p*** |
| Salary scale | -0.109 | 0.169 | 0.153 | 0.053 | -0.211** | 0.007 | -0.191* | 0.015 |
| Medical care cost | -0.003 | 0.972 | 0.396** | 0.000 | -0.146 | 0.065 | -0.185* | 0.019 |
| Breast- and/or formula feeding method | 0.084 | 0.287 | -0.073 | 0.357 | 0.164* | 0.038 | -0.057 | 0.475 |

$r_S$ = Spearman rho coefficient
*. Correlation is significant at the 0.05 level (2-tailed)
**. Correlation is significant at the 0.01 level (2-tailed)

*p* = two-tailed significant factor

Weight-for-age z-scores were significantly associated with maternal age, paternal age, gestational age, exclusive breastfeeding duration, infant age when complementary food was introduced, infant age when more solid food than milk products was consumed (all from Table 4.9), maternal education, household occupancy and weight at birth (Table 4.15). Maternal and paternal age indicated a strong positive ($r$ = 0.75) association as the correlation coefficients were closer to positive one (+1.0) (Table 4.18) with the VIF value of 1.0 that showed that they were not collinear variables (Table 4.17), but proxy variables. For further statistical analyses it was decided to use maternal age as it had a stronger association ($r$ = 0.245) with weight-for-age z-scores than paternal age ($r$ = 0.209) (Table 4.9). As previously explained, gestational age and weight at birth were proxy variables, but weight at birth had a stronger association (Table 4.15) with weight-for-age z-score than gestational age (Table 4.9). Exclusive breastfeeding duration was not collinear to infant age when solid (complementary) food products introduced into the diet or infant age when infant diet contains more solid food products than milk products (Table 4.17), but the former significantly correlated with the latter variables (Table 4.19) which made them proxy variables.

Weight-for-length-for-age z-scores significantly correlated with maternal age, paternal age, infant age when infant diet contains more solid food products than milk products (Table 4.9), household occupancy, number of maternal dependents and salary scale (Table 4.15). Maternal age significantly correlated ($r$ = 0.593) with number of maternal dependents (Table 4.18). Household occupancy was not collinear to number of maternal dependents, but it was significantly associated with each other ($r$ = 0.294) (Table 4.18). In addition, salary scale was also significantly correlated with number of maternal dependents (Table 4.20). Hence, the number of maternal dependents were not considered in further weight-for-length-for-age z-score analyses.

Head circumference-for-age z-scores significantly correlated with maternal age, paternal age, gestational age, exclusive breastfeeding duration, infant age when solid (complementary) food products introduced into infant diet, infant age when infant diet contains more solid food products than milk products (Table 4.9), maternal education and weight at birth (Table 4.15).

## 4.3 UNIVARIATE AND MULTIVARIATE REGRESSION ANALYSES

Results in this subsection represent the regression analyses and best fit models for each of the z-scores when all participant data in this study were combined, irrespective of the age, sex and SES groups. Age and sex are major contributors to the difference in length, weight and head circumference of the infants, and therefore the z-scores were used as they are age-standardised. The data are presented as maternal explanatory variables, and pre- and post-natal infant explanatory variables.

Not all the explanatory information collected from the various questionnaires was used. Only those that showed a significant correlation using measures of association as discussed in the previous subsection (4.2.4) of the results were included in the regression analyses. Not all explanatory variables that showed a significant correlation in a univariate regression model were included in the following process, as they were proxies for other more significantly correlated variables. On the other hand, variables that were not significantly associated with a particular z-score may have contributed to the best fit models and were included in the analysis process.

All regression s represented in the tables, consists of the Pearson's *r* coefficient, the adjusted $R^2$, the F-value of the model with its significance factor (*p*) and the standardised beta (β) coefficient with the significance factor (*p*) of each of the explanatory variable(s) in the model.

### 4.3.1 LENGTH-FOR-AGE Z-SCORE

As previously stated, the explanatory variables that significantly correlated with the length-for-age z-score was maternal age, maternal education, gestational age, weight at birth, exclusive breastfeeding duration, and infant age when complementary (solid) food was introduced into the infant's diet (Table 4.21). Maternal age and maternal education showed a low correlation ($r$ = 0.062), and therefore, both were used in the multivariate regression models. Gestational age and weight at birth were determined to be strongly associated, and thus, only one of the two variables was used. Salary scale was not significant in the univariate regression model 3 in Table 4.21, nor in the bivariate regression models 7 and 8, yet was significant in the multivariate model 12.

**Table 4.21: Univariate and multivariate regression models for length-for-age z-scores based on maternal and infantile explanatory variables, irrespective of socio-economic status (SES) group.**

| Model number | Explanatory variables | Pearson's *r* coefficient | Adjusted $R^2$ | F-value (*p*) | | Beta coefficient (*p*) | |
|---|---|---|---|---|---|---|---|
| | | | | F | *p* | β | *p* |
| 1 | Maternal age (years) | 0.169 | 0.022 | 4.680 | 0.032 | 0.169 | 0.032 |
| 2 | Maternal education (years) | 0.295 | 0.081 | 15.149 | 0.000 | 0.295 | 0.000 |
| 3 | Salary scale | 0.112 | 0.006 | 2.011 | 0.158 | 0.112 | 0.158 |
| 4 | Gestational age (weeks) | 0.220 | 0.042 | 8.078 | 0.005 | 0.220 | 0.005 |
| 5 | Age complementary food introduced (months) | 0.205 | 0.036 | 6.975 | 0.009 | 0.205 | 0.009 |
| 6 | Maternal age (years) + Maternal education (years) | 0.331 | 0.099 | 9.747 | 0.000 | 0.151<br>0.286 | 0.046<br>0.000 |
| 7 | Maternal age (years) + Salary scale | 0.227 | 0.040 | 4.278 | 0.016 | 0.203<br>0.156 | 0.012<br>0.052 |
| 8 | Maternal education (years) + Salary scale | 0.310 | 0.096 | 8.357 | 0.000 | 0.289<br>0.119 | 0.000<br>0.118 |
| 9 | Maternal education (years) + Gestational age (weeks) | 0.373 | 0.129 | 12.798 | 0.000 | 0.302<br>0.229 | 0.000<br>0.002 |
| 10 | Maternal education (years) + Age complementary food introduced (months) | 0.362 | 0.120 | 11.918 | 0.000 | 0.298<br>0.210 | 0.000<br>0.005 |
| 11 | Gestational age (weeks) + Age complementary food introduced (months) | 0.281 | 0.067 | 6.794 | 0.002 | 0.194<br>0.177 | 0.013<br>0.023 |
| 12 | Maternal age (years) + Salary scale + Maternal education (years) | 0.359 | 0.112 | 7.716 | 0.000 | 0.186<br>0.160<br>0.279 | 0.016<br>0.039<br>0.000 |
| 13 | Maternal education (years) + Gestational age (weeks) + Exclusive breastfeeding (months) + Age complementary food introduced (months) | 0.416 | 0.152 | 8.150 | 0.000 | 0.304<br>0.197<br>0.047<br>0.157 | 0.000<br>0.009<br>0.587<br>0.066 |

Additional regression models for length-for-age were analysed incorporating exclusive breastfeeding duration, but as in model 13 exclusive breastfeeding duration did not significantly contribute to the model. This is shown in model 13 where the exclusive breastfeeding duration variable did not significantly contribute to the model. It was previously stated that both exclusive breastfeeding duration ($r$ = 0.161) and infant age when complementary (solid) food was introduced into the infant's diet ($r$ = 0.205) were both significantly correlated to length-for-age z-score (Table 4.9). Yet they were highly correlated with each other, and therefore, only one of these variables could be used in the regression analyses as they were proxies for each other. The effect of proxy variables was illustrated in model 13 (Table 4.21). Table 4.21 showed that maternal education was a significant contributing factor in any of the regression models. Unlike what was expected, maternal smoking and drinking during pregnancy and/or breastfeeding period, showed no significant correlation with the length-for-age z-score, and therefore, was not used as a variable in the regression models (Table 4.22). The final regression was significant and explained just over 24.0% of the variance in age-standardised length-for-age.

**Table 4.22: Eta measures plus a Mann-Whitney U significance test were used to analyse each z-score associated with various explanatory variables, irrespective of socio-economic status (SES) group.**

| **Explanatory variable** | **zlen** | | **zwei** | | **zwfl** | | **zhc** | |
|---|---|---|---|---|---|---|---|---|
| | Eta value | ***p*** | Eta value | ***p*** | Eta value | ***p*** | Eta value | ***p*** |
| Weight at birth | 0.221 | **0.003[B]** | 0.232 | **0.003[B]** | 0.127 | 0.125 | 0.185 | **0.002[B]** |
| Maternal smoking during pregnancy | 0.164 | 0.104 | 0.070 | 0.310 | 0.034 | 0.812 | 0.058 | 0.322 |
| Maternal smoking during breastfeeding period | 0.125 | 0.209 | 0.084 | 0.178 | 0.003 | 0.846 | 0.047 | 0.405 |
| Maternal drinking during pregnancy | 0.079 | 0.280 | 0.132 | 0.101 | 0.115 | 0.129 | 0.095 | 0.136 |
| Maternal drinking during breastfeeding period | 0.069 | 0.537 | 0.075 | 0.279 | 0.093 | 0.134 | 0.067 | 0.637 |

zlen = length-for-age z-score

zwei = weight-for-age z-score

zwfl = weight-for-length-for-age z-score

zhc = head circumference-for-age z-score

M-W U = Mann-Whitney U test

*p* = two-tailed significant factor
Bonferroni: $\boldsymbol{p \leq 0.010}$[B] indicates significant difference.

### 4.3.2 WEIGHT-FOR-AGE Z-SCORE

In Table 4.23, explanatory variables that showed significant correlation with weight-for-age, were maternal age, paternal age, household occupancy, maternal education, gestational age, weight at birth, exclusive breastfeeding duration, infant age when complementary (solid) food was introduced, and infant age when more solid food was consumed than milk products (Tables 4.9 and 4.15). Maternal age and paternal age were highly correlated though were not collinear variables (Table 4.17). Therefore, only maternal age was used as it had a stronger correlation coefficient ($r$ = 0.245) than paternal age ($r$ = 0.209) (Table4.18).

Similarly, maternal age and maternal education were significantly correlated with household occupancy (Table 4.19). In model 7 of Table 4.23 the effect (highlighted in red) of this significant correlation between maternal age and household occupancy was evident as the standardised beta (β) coefficient of household occupancy was 0.133 and household occupancy had no significant contribution to the model. Yet, in model 8 of Table 4.23 household occupancy does significantly contribute to the model in conjunction with maternal education. Furthermore, in the multivariate regression model 11 in Table 4.23, household occupancy with both maternal age and education had an even stronger contribution to the model.

As previously stated, gestational age and weight at birth were determined as proxies for each other. Weight at birth had a stronger correlation ($r$ = 0.323; Table 4.22) than gestational age ($r$ = 0.177; Table 4.9) with weight-for-age, thus weight at birth was used for the multivariate regression analysis. Similar to length-for-age, exclusive breastfeeding duration were significantly correlated with gestational age and infant age complementary food was introduced. Therefore, exclusive breastfeeding duration was excluded from the multivariate regression models.

Regression analyses were not run for maternal smoking and drinking, as they had similar results as that for length-for-age. None proved to be significant either as single variables or multi-variables. The final regression model was significant and explained just over 18.0% of the variance in age-standardised weight-for-age.

**Table 4.23: Univariate and multivariate regression models for weight-for-age z-scores based on maternal, and infantile explanatory variables, irrespective of socio-economic status (SES) group.**

| Model number | Explanatory variables | Pearson's *r* coefficient | Adjusted $R^2$ | F-value (*p*) | | Beta coefficient (*p*) | |
|---|---|---|---|---|---|---|---|
| | | | | F | *p* | β | *p* |
| 1 | Maternal age (years) | 0.245 | 0.054 | 10.111 | 0.002 | 0.245 | 0.002 |
| 2 | Maternal education (years) | 0.205 | 0.036 | 6.970 | 0.009 | 0.205 | 0.009 |
| 3 | Household occupancy | 0.171 | 0.023 | 4.750 | 0.031 | 0.171 | 0.031 |
| 4 | Weight at birth | 0.232 | 0.048 | 9.013 | 0.003 | 0.232 | 0.003 |
| 5 | Age complementary food introduced (months) | 0.225 | 0.045 | 8.479 | 0.004 | 0.225 | 0.004 |
| 6 | Maternal age (years) + Maternal education (years) | 0.310 | 0.085 | 8.384 | 0.000 | 0.233<br>0.191 | 0.003<br>0.013 |
| 7 | Maternal age (years) + Household occupancy | 0.271 | 0.065 | 6.549 | 0.002 | 0.222<br>0.133 | 0.005<br>0.089 |
| 8 | Maternal education (years) + Household occupancy | 0.295 | 0.075 | 7.481 | 0.001 | 0.247<br>0.229 | 0.002<br>0.004 |
| 9 | Weight at birth + Exclusive breastfeeding (months) | 0.276 | 0.065 | 6.537 | 0.002 | 0.208<br>0.153 | 0.008<br>0.050 |
| 10 | Weight at birth + Age complementary food introduced (months) | 0.298 | 0.077 | 7.674 | 0.001 | 0.198<br>0.190 | 0.011<br>0.015 |
| 11 | Maternal age (years) + Maternal education (years) + Household occupancy | 0.361 | 0.113 | 7.771 | 0.000 | 0.197<br>0.238<br>0.193 | 0.011<br>0.002<br>0.015 |

### 4.3.3 WEIGHT-FOR-LENGTH-FOR-AGE Z-SCORE

Explanatory variables that significantly correlated with weight-for-length-for-age were maternal age, paternal age, household occupancy, number of maternal dependents, salary scale and infant age when more solid food was consumed than milk products. Maternal age had a stronger correlation ($r$ = 0.177) with this z-score than paternal age ($r$ = 0.171), and therefore, was used in the regression analyses. Maternal age was significantly correlated with number of maternal dependents ($r$ = 0.593) and household occupancy ($r$ = 0.170) (Table 4.18). Household occupancy was significantly associated with number of maternal dependents and salary scale (Table 4.20). Therefore, it was decided to exclude the number of maternal dependents and salary scale from the analyses. Although household occupancy affected maternal age in a bivariate regression model where the significance factor for maternal age was 0.066 (model 6; Table 4.24), the effect was less in model 10, and maternal age was a significant contributor. The final model (model 10; Table 4.24) only accounted for 8.3% of the variance in age-standardised weight-for-length-for-age of the study cohort.

Both number of adults and number of children residing in a household showed individual significant correlation with weight-for-length-for-age, but as stated previously they were collinear variables as household occupancy is a function of the number of adults and children living together in the same household. Another explanatory variable from the HFIAS questionnaire, where the mother was asked about "the limited variety of food available due to a lack of financial resources", was significantly correlated ($r$ = 0.162, $p$ = 0.040) with weight-for-length-for-age, but when used in the regression analysis did not significantly contribute to the best fit model ($r$ = 0.098, $p$ = 0.233).

**Table 4.24: Univariate and multivariate regression models for weight-for-length-for-age z-scores based on maternal explanatory variables, irrespective of socio-economic status (SES) group.**

| Model number | Explanatory variables | Pearson's *r* coefficient | Adjusted $R^2$ | F-value (*p*) | | Beta coefficient (*p*) | |
|---|---|---|---|---|---|---|---|
| | | | | F | *p* | β | *p* |
| 1 | Maternal age (years) | 0.177 | 0.025 | 5.114 | 0.025 | 0.177 | 0.025 |
| 2 | Maternal number of dependents | 0.216 | 0.041 | 7.756 | 0.006 | 0.216 | 0.006 |
| 3 | Household occupancy | 0.210 | 0.038 | 7.255 | 0.008 | 0.210 | 0.008 |
| 4 | Age complementary food introduced (months) | 0.131 | 0.011 | 2.770 | 0.098 | 0.131 | 0.098 |
| 5 | Maternal age (years) + Maternal number of dependents | 0.224 | 0.038 | 4.165 | 0.017 | 0.074<br>0.172 | 0.442<br>0.077 |
| 6 | Maternal age (years) + Household occupancy | 0.254 | 0.052 | 5.399 | 0.005 | 0.145<br>0.185 | 0.066<br>0.020 |
| 7 | Maternal age (years) + Age complementary food introduced (months) | 0.262 | 0.039 | 4.266 | 0.016 | 0.185<br>0.142 | 0.018<br>0.069 |
| 8 | Maternal number of dependents + Household occupancy | 0.265 | 0.058 | 5.920 | 0.003 | 0.169<br>0.160 | 0.037<br>0.049 |
| 9 | Household occupancy +<br>Age complementary food introduced (months) | 0.246 | 0.048 | 5.050 | 0.007 | 0.211<br>0.129 | 0.007<br>0.098 |
| 10 | Maternal age (years) + Household occupancy + Age complementary food introduced (months) | 0.153<br>0.191<br>0.190 | 0.048<br>0.015<br>0.014 | 0.153<br>0.191<br>0.190 | 0.048<br>0.015<br>0.014 | 0.153<br>0.191<br>0.190 | 0.048<br>0.015<br>0.014 |

### 4.3.4 HEAD CIRCUMFERENCE-FOR-AGE Z-SCORE

As previously stated, the explanatory variables that significantly associated with head circumference-for-age were maternal age, paternal age, maternal education, gestational age, weight at birth, exclusive breastfeeding duration, infant age when complementary (solid) food was introduced, and infant age when more solid food was consumed than milk products (Tables 4.9, 4.15 and 4.22). As with all previous models, maternal age was a significant contributing factor to the head circumference-for-age regression analyses (Models 1, 5-7 and 11-12; Table 4.25). So too was maternal education (Models 2, 8-9 and 12) and gestational age (models 3, 6, 8, 10 and 12) in Table 4.25. Weight at birth although had a stronger association with head circumference-for-age than gestational age, but when weight at birth were included in the regression analysis rather than gestational age it accounted for 14.5% of variance compared to 16.1% for the latter. Therefore, it was excluded from the final analysis.

In the head circumference-for-age regression analysis, although gestational age and exclusive breastfeeding duration were highly correlated (previously shown; Table 4.19), these two variables both contributed significantly to regression Models 10-12 (Table 4.25). The final model (model 4; Table 4.26) accounted for 16.1% of the variance in age-standardised head circumference-for-age of the study cohort.

FINAL MULTIVARIATE REGRESSION MODELS

The final multivariate regression models for the age-standardised length-for-age, weight-for-age, weight-for-length-for-age, and head circumference-for-age are presented in Table 4.26. Each model showed the explanatory variables that were used in the model, their standardised beta coefficients with respective significance in the model, and finally the percentage variance accounted for by each model, based on the adjusted $R^2$ value.

**Table 4.25: Univariate and multivariate regression models for head circumference-for-age z-scores based on maternal infantile explanatory variables, irrespective of socio-economic status (SES) group.**

| Model number | Explanatory variables | Pearson's *r* coefficient | Adjusted $R^2$ | F-value (*p*) | | Beta coefficient (*p*) | |
|---|---|---|---|---|---|---|---|
| | | | | F | *p* | β | *p* |
| 1 | Maternal age (years) | 0.213 | 0.039 | 7.530 | 0.007 | 0.213 | 0.007 |
| 2 | Maternal education (years) | 0.189 | 0.030 | 5.897 | 0.016 | 0.189 | 0.016 |
| 3 | Gestational age (weeks) | 0.236 | 0.050 | 9.391 | 0.003 | 0.236 | 0.003 |
| 4 | Exclusive breastfeeding (months) | 0.255 | 0.059 | 11.035 | 0.001 | 0.255 | 0.001 |
| 5 | Maternal age (years) + Maternal education (years) | 0.276 | 0.065 | 6.524 | 0.002 | 0.202<br>0.177 | 0.009<br>0.022 |
| 6 | Maternal age (years) + Gestational age (weeks) | 0.317 | 0.089 | 8.853 | 0.000 | 0.212<br>0.236 | 0.006<br>0.002 |
| 7 | Maternal age (years) + Exclusive breastfeeding (months) | 0.334 | 0.112 | 9.926 | 0.000 | 0.216<br>0.258 | 0.004<br>0.001 |
| 8 | Maternal education (years) + Gestational age (weeks) | 0.307 | 0.083 | 8.229 | 0.000 | 0.196<br>0.242 | 0.010<br>0.002 |
| 9 | Maternal education (years) + Exclusive breastfeeding (months) | 0.320 | 0.091 | 9.008 | 0.000 | 0.194<br>0.258 | 0.011<br>0.001 |
| 10 | Gestational age (weeks) + Exclusive breastfeeding (months) | 0.318 | 0.090 | 8.865 | 0.000 | 0.194<br>0.217 | 0.013<br>0.005 |
| 11 | Maternal age (years) + Gestational age (weeks) + Exclusive breastfeeding (months) | 0.384 | 0.131 | 9.034 | 0.000 | 0.215<br>0.192<br>0.220 | 0.004<br>0.011<br>0.004 |
| 12 | Maternal education (years) + Gestational age (weeks) + Exclusive breastfeeding (months) | 0.375 | 0.124 | 8.550 | 0.000 | 0.199<br>0.199<br>0.219 | 0.008<br>0.009<br>0.004 |

**Table 4.26: Best fit multivariate regression models for length-for-age, weight-for-age, weight-for-length-for-age and head circumference-for-age z-scores based on explanatory variables, irrespective of socio-economic status (SES) group.**

| Model number | Z-score model | Explanatory variables | Pearson's *r* coefficient | Adjusted $R^2$ | F-value (*p*) | | Beta coefficient (*p*) | |
|---|---|---|---|---|---|---|---|---|
| | | | | | F | *p* | β | *p* |
| 1 | Length-for-age | Maternal age (years) + Maternal education (years) + Gestational age (weeks) + Salary scale + Household occupancy + Infant age complementary food introduced (months) | 0.496 | 0.246 | 8.324 | 0.000 | 0.177<br>0.334<br>0.197<br>0.207<br>0.171<br>0.205 | 0.017<br>0.000<br>0.006<br>0.005<br>0.023<br>0.005 |
| 2 | Weight-for-age | Maternal age (years) + Maternal education (years) + Household occupancy + Weight at birth + Infant age complementary food introduced (months) | 0.457 | 0.183 | 8.117 | 0.000 | 0.216<br>0.231<br>0.181<br>0.169<br>0.209 | 0.004<br>0.002<br>0.017<br>0.021<br>0.005 |
| 3 | Weight-for-length-for-age | Maternal age (years) + Household occupancy + Infant age complementary food introduced (months) | 0.316 | 0.083 | 5.786 | 0.001 | 0.153<br>0.191<br>0.190 | 0.048<br>0.015<br>0.014 |
| 4 | Head circumference-for-age | Maternal age (years) + Maternal education (years) + Gestational age (weeks) + Exclusive breastfeeding (months) | 0.426 | 0.161 | 8.664 | 0.000 | 0.204<br>0.186<br>0.198<br>0.222 | 0.006<br>0.011<br>0.008<br>0.003 |

# CHAPTER 5: DISCUSSION

This research was initiated based on the hypothesis that the WHO child growth standard may not be applicable to all South African population groups, specific anthropometric measures or at specific phases of physical development as noted by Fenn and Penny (2008), Natale and Rajagapolan (2014), Vignerová *et al*. (2015), Christesen *et al*. (2016), Inokuchi *et al*. (2018), Tian *et al*. (2019) and other researchers. Accordingly, the research aims were to; (i) collect and analyse baseline anthropometric data on healthy, full-term MA infants that may be applied in various spheres of public health, (ii) analyse these MA infants' linear growth against the WHO growth standard, (iii) determine the growth trajectory of this cohort, (iv) identify relationships between growth trajectories and maternal and early life variables, and (v) evaluate the extent to which these variables might explain the variance in growth patterns in these infants. At the outset of this research, the intergenerational effects of environmental conditions on linear growth were highlighted. These intergenerational effects on growth trajectory due to ancestral admixture, and socio-economic and socio-political disparities of the MA population in South Africa may have attributed to the results of this research. In this section of the thesis, the results are discussed and compared to other published research especially those that entail the same population group in South Africa to further understand linear growth of MA individuals, and factors that may have contributed to the variance determined in the results. Further, the data gathered may provide a better understanding of the potential causal pathways for variation in child growth trajectories in MA infants in South Africa, and finally, the effect linear growth differences from the WHO standard may result in adult-onset NCDs.

## 5.1 ANTHROPOMETRY

### 5.1.1 ANTHROPOMETRIC TRENDS

It was evident from the results that MA boys were physically bigger than girls, though anthropometric differences between MU-SES girls and L-SES boys were much smaller with, for example, the greatest mean length difference being 1 cm in the 0 – 5.9 months age group. The WHO growth standard shows that boys generally tend to be taller and weigh more than girls (De Onis *et al*., 2006), and hence, should not have such small difference between the sexes. The results show that the L-SES group boys had greater difference in standard deviation from the WHO growth median than the MU-SES group girls, and therefore, it can be said that the L-SES group boys were smaller than expected, and the girls from the MU-SES group were closer to being on par with the WHO growth median. Furthermore, the fact that generally no significant differences were found in infants older than 6 months, either between the SES groups or the sexes from the SES groups, indicated that some type of catch-up growth could have occurred in the L-SES group infants to be on par with the MU-SES group. It is not to say that low socio-economic backgrounds are cause for growth differences, but rather that differences in environmental conditions may have caused an intergenerational phenotypic expression affecting growth trajectory similar to what Walker *et al*. (2006) described. The authors concluded that due to intergenerational nutritional adaptation, there was an initial slow growth period that increase later in the child's life. A similar argument was put forth for MA individuals in Arendse *et al*. (2022). This growth increase would have occurred between the ages of 4 to 6 months for length (Figure G.1), and 6 to 9 months for weight (Figure G.2), as most infants (87.9% or 51/58) in the 6 – 11.9 months age group were in this age range (Appendix G). When the length-for-age and weight-for-age z-scores in the 0 – 5.9 months category were considered, the mean and median values were negative (Table H.1), indicating an overall trend in the infant cohort, especially in the L-SES group, to have length and weight measurements below the norm of the international standard (0). Another interesting observation was the trend for male median length and weight z-scores to remain negative for the 6 – 11.9 months age group, but the girls had all positive medians in this age group, which was different to the trend observed for the mean values of the z-scores. This meant that the distribution (median) of length and weight for boys tended to be below the international standard norm for a longer time period whereas girls were either on par or slightly above it. At 6 months boys and girls had similar length distributions (Figure G.1), but boys tended to have lower weights than the girls (Figure G.2). This would account for the lower weight-for-length ratio (Figure F.3) of boys compared to girls at this age. This might indicate that girls tended to 'recover' linear growth faster than their male counterparts, yet it might also indicate sex dimorphism in growth trajectory. Another theory may be that the study cohort's infants tended to be smaller for gestational age, and a natural growth acceleration occurred in the 4 to 9 months post-natal phase (Huang *et al*., 2019; Sinha *et al*., 2021). This is evident in Sartorius *et al*.'s (2020) results where infants at birth ('0' years) have nearly double stunting prevalence (they are shorter in length), if not more, than those at 12 months ('1' year) from 2008 – 2017.

Findings from three comparative studies by Oelofse *et al.* (2002), Budree *et al*. (2017) and Barnett *et al*. (2021) were then evaluated with the current study's results. All three studies collected data in similar peri-urban areas (with 5 km between the areas) between 42 to 51 km from the current study's L-SES location. Hence, these MA individuals have similar ecogeographical and socio-political intergenerational influences as the infants who formed part of this study's low socio-economic background cohort. Oelofse *et al*. collected cross-sectional data in 1998 in a "*disadvantaged*" community of infants aged 6 – 12 months, Budree *et al*. collected longitudinal data from 2012 to 2014 also in disadvantaged communities for infants 0 – 12 months at various intervals within the 12-month period, and Barnett *et al*. used longitudinal data (although they describe it as cross-sectional) from the "*Drakenstein Child Health Study*" (Donald *et al*., 2018) at birth and at 24 months. The first two studies separated African Descent (AD) and MA results, but not sex whereas the latter separated sex results but not AD and MA population groups. Oelofse *et al*. (2002) used a different standard (National Center for Health Statistics reference median) to the last two studies, but the comparative research data from them were similar to this study's overall length results [1998: 68.6 cm (4.9SD); 2019/20: 70.1 cm (3.3SD)], and overall weight results [1998: 8.6 kg (1.7SD); 2019/20: 8.5 kg (1.5SD)] results with the current study. These studies did not exclude HIV+ mothers, and a meta-analysis by Xiao *et al*.' (2015) presented research findings that substantiated LBW for HIV+ mothers that might have affected results. In general, all 4 studies show a trend of much lower length measures than weight measures from birth with a steady increase to age 12 months than the international norm, with weight measures that increased faster over this period than length, which resulted in above norm weight-for-length ratios.

The current study's results indicated that the 12 – 18 months infants were on par with the international norm. Yet, with closer investigation of data distribution, it was observed that for length there was a decrease in length-for-age but an increase of weight-for-length-for-age between infants at 12 months and those at 18 months. Budree *et al*. (2017) and Barnett *et al*. (2021) showed similar results for infants aged 12 months and 24 months, respectively, as data were collected in the same area (TC Newman, Paarl). Nationally, Sartorius *et al*. (2020) indeed followed the same trend as the results of this study where toddlers aged 2 years were more likely to be shorter for their age than 1 year old infants. It was understood that no conclusive assessment/statement could be reached/provided because (i) the data were mostly cross-sectional, and (ii) cohort sizes and structures were different for each study. Yet the notable trend of a decreased length-for-age and increased weight-for-length from 12 – 24 months was evident across the studies. In the current study this trend was observed in both SES groups. No inferences could be made of these trends, but it may suggest there is a trend of South African children being below the international length norm, and the high prevalence of above the weight at a specific age (increasing prevalence of obesity).

Head circumference measurement median for boys aged 0 – 5.9 months tended to be slightly below the international standard median whereas girls were slightly above although both had negative mean values. This negative trend for the boys were due largely to data from the L-SES group (Table H.1). Le Roux *et al*. (2020) similarly showed that nearly one in every four girls aged 6 weeks in their research had head circumference measurements above the WHO growth norm. Le Roux *et al*.'s (2020) cohort was from the Northern Cape Province where MA individuals have greater Khoe-San genetic input (Petersen *et al*., 2013) as mentioned on page 19 of this thesis, yet the current study showed a similar head circumference trend to theirs even though they do not specify ancestral lineage in their publication. Infants older than 6 months from both sexes were on par with the international standard. Based on the median z-score values in the 6 – 11.9 months age group, except MU-SES boys, most measurements translated as above a +0.5 SD from the WHO head-circumference-for-age z-score norm (0). The change between these statistical analyses of head circumference results was possibly due to the higher frequency, and thus distribution of group data, of L-SES boys compared to MU-SES boys. Another interesting observation of the head circumference results for the boys age groups, was that the boys from the L-SES group had more than +0.8 SD mean z-score (median difference was > +1SD) difference between the 0 – 5.9 months and 6 – 11.9 months age groups, but because the data were not longitudinal no inferences could be made with certainty. Possible future research of the MA population should consider a longitudinal study to verify if this is a general trend that distinctly differs from the international norm. In most part, infants older than 6 months were close to the WHO growth norm (0) for head circumference measurements; *i.e*. the mean head circumference-for-age z-score (standard deviation) was closer to zero.

Therefore, based on the results it was concluded that infants younger than 6 months that participated in this research study were on average below the international norm for all three anthropometric measurements. This suggests that catch-up growth might have occurred between the ages of 4 – 9 months for length, weight and head circumference or, the growth trajectory of the infants may have differed from the international norm. Benjamin-Chung *et al*.'s (2021) research on linear growth faltering in LMICs, of which SA was part of, showed that 14% of children were born with mean length-for-age between –1 and 0 at birth, and then they further stated that "*new incidence of stunting was highest at birth and declined steadily to 3.3% per month by age 4 months*". Although the data for infants in this cohort was not longitudinal as Benjamin-Chung *et al*.'s data, it appeared to follow a similar trend. Therefore, it may indicate that the infants had a different growth starting point and trajectory within the first 6 months post-natal compared to the WHO MGRS 2006 growth standard.

### 5.1.2 ABNORMAL GROWTH INDICATORS

The age-sex-adjusted z-scores made comparative analyses of growth abnormalities possible between this study and other South African research that has dealt with infants under five years of age, and especially MA infants from the Western Cape Province (WC) region. Although genetic differences were highly likely between the different studies' cohorts, especially when other studies' results were based on combined data from different population groups in South Africa, these were noted when inferences were made. It was surmised from the results that 5% or less of the study's total infant cohort were stunted, wasted, overweight or obese, and these were predominantly found in the L-SES group and especially the boys. Head circumference growth abnormalities were found in 11.2% of infants but were predominantly macrocephalic (> +2 SD) in infants older than 6 months. All significant differences found in the different age groups according to the various categories were in those younger than 6 months. As a group, they had more negative mean and median z-scores (below the median of '0' or below the growth 'norm') across the four physical growth parameters compared to those older than 6 months.

This was far less than what the SADHS reported in 2016 (National Department of Health *et al*., 2017). These differences may be related to differences in sampling methods, genetic and/or ancestral intergenerational influences. In the present study, we excluded infants with HIV/AIDS, tuberculosis and other chronic diseases or illnesses known to affect growth. In addition, the study cohort only comprised MA individuals whereas the SADHS comprised of all population groups in SA. No inferences between the SADHS and this study could be made with certainty regarding comparative growth abnormality prevalence as the scope of this study was exponentially smaller than the SADHS and exclusion criteria biases between the two studies.

#### 5.1.2.1 STUNTING

Four comparative studies, 60 – 70 km from the current study's research locations, had negative (below the median of 0) length-for-age z-scores from birth to age 24 months. Oelofse *et al*. (2002) showed 18% stunting in a peri-urban region for an age cohort of 6 – 12 months (mean = 8.9 months) and Budree *et al*. (2017) reported MA longitudinal results of 22% (birth) to 17% (12 months) stunting. Like Oelofse (data collected 1998) who had a negative length-for-age mean z-score (-0.95) at a mean age of 8.9 months, Budree (data collected 2012-2014) also had a negative z-score for MA infants aged 6 (-0.7) to 12 (-0.6) months in a similar peri-urban area. Furthermore, Donald *et al*. (2018) had a negative birth length z-score (-0.03) for MA infants from 2012 to 2015 and separated AD and MA but didn't state if HIV exposed/infected infants were excluded. Barnett *et al*. (2021) averaged a z-score of -1.16 for infants aged 24 months although they did not separate MA and AD, and they included HIV exposed infants as stated above. The L-SES group in this study had similar negative values to the findings from these 'disadvantaged' communities described above. Du Plessis *et al*. (2018) collected data, 115 km (L-SES) to 150 km (MU-SES) from the current study's research locations, in what could be described as an agricultural town, and their length z-scores indicated a higher prevalence of stunting compared to the peri-urban areas that corresponds to Ardington and Case (2009) who reported that stunting prevalence was higher in rural areas than in urban areas across SA, irrespective of population group, with nearly double the percentage of MA and AD children tended to be stunted compared with European and Indian descendants.

On a provincial scale for the Western Cape Province, Senekal *et al*. (2019) used data from 7 national surveys between 1994 to 2016 and calculated an average of 25.7% stunted and severely stunted children aged 1 - <5 years in a formal urban area, 16.5% in an informal urban area, and 29.3% in rural areas, of which 68% of children were MA. Nationally (SA), Zeke and McIntyre (2003) reported 18.8% stunting for MA, Ardington and Case (2009) reported 19.5% stunting in children aged 6 months to 14 years, and both these publications formed part of Said-Mohamed *et al*.'s (2015) systematic review that reported a 17% (1993) to 35% (2003) stunting prevalence. Faber *et al*. (2015) showed 13.9% stunting prevalence in pre-school children in an urban area (mean = 3.8 years; mixed population groups). It should be stated that different international standards of z-scores were used for the 1993 – 2003 period (National Center for Health Statistics recommended by WHO 1986) compared to the 2013 – 2018 period (WHO MGRS 2006). Le Roux *et al*. (2020) collected data in the Northern Cape Province (NC; that has the second largest MA population in SA after WC) that found 13.0 to 14.1% and 17.7 to 30.8% stunting rate from birth to 6 weeks (1.38 months) in girls and boys, respectively. These results included all population groups. Le Roux and her collaborators' research data were in district municipalities where population dynamics were 50.4% AD and 40.3% MA (Le Roux *et al*., 2020).

Comparisons between the current study and all these publications, were to evaluate their general trends of linear growth in a local area, at provincial level and a national level. It was evident that the stunting prevalence in the current study was vastly different to other research results. The question remained: Why? Most studies were cross-sectional, but only one mentioned the exclusion of 'unhealthy' (chronic disorders, disease) children. Mabaya *et al*. (2021) reported lower length-for-age in HIV exposed but uninfected or infected infants, and LaCourse *et al*. (2016) reported the affect maternal tuberculosis could have on infant development. With the high prevalence of both these diseases in SA (Statistics South Africa, 2005; 2021), and the lack of reporting of inclusion and exclusion criteria based on these two diseases, it may have been the reason the current study had a much lower stunting rate compared to other South African publications. Faber (2007) showed that even iron deficiency (anaemic versus non-anaemic) had an impact on physical development in infants. Hence, it is argued that although there was a lower length-for-age than the international norm within the first 6 months postnatal, the drastic differences between the current study and previous research might have been based on the inclusion criteria between the studies. The difference in prevalence rates might also be related to genetic differences in ancestral lineage and intergenerational effects between the current study's infant cohort and previous provincial and national publications, but this was outside the scope of the current study's data.

Furthermore, both Zhang *et al*. (2015) and Li *et al*. (2020) presented results that showed maternal height affected infant size at birth, with the latter presenting logistic regression results indicating that maternal height was strongly associated with stunting in children. It has been shown that South African MA adults, especially in disadvantaged communities, were shorter in stature than those of African or European Descent (Arendse, 2018). It may be reasoned that even if these infants were born below the norm, especially in disadvantaged communities, their older counterparts had caught up to the international norm by age 6 – 9 months, yet by aged 18 – 24 months there was a decrease in the linear growth rate of these infants including evidence from other publications. It should also be highlighted that Sartorius *et al*.'s (2020) stunting prevalence at 12 months, were only half, or a third (depending on the year; 2008 - 2017) of what the 2016 SADHS reported, indicating prevalence discrepancies at a national level.

#### 5.1.2.2 UNDERWEIGHT, WASTED, OVERWEIGHT AND OBESITY

Underweight prevalence was low in the current study as per results reported in other publications for the first 24 months of the infants' lives (Oelofse *et al*., 2002; Du Plessis *et al*., 2016; Budree *et al*., 2017; Donald *et al*., 2018; Barnett *et al*., 2021). Monyeki *et al.* (2015) concluded that there was a greater prevalence of boys being underweight than girls, which was also evident in the current study especially in those that were older than 6 months. Senekal *et al*. (2019) reported a 5.7% underweight in a formal urban setting in the WC. This study's weight-for-age results for those younger than 6 months tended to be distributed below the international norm, irrespective of SES group, that might suggest a general trend that MA infants are smaller when born with an increase in weight-for-age for those older than 6 months. Li *et al*. (2020) reported a strong association between short maternal height and underweight. Although we were unable to measure weight and height of the mothers in the current study, Steyn *et al*. (1990) reported a mean adult height of 156.0 cm for MA females and 167.6 cm for MA males in the same metropole as this study, whereas BusinessTech South Africa (2016) reported a national average of 158.0 cm for adult females who ranked 76$^{th}$ shortest average height in the world. This shows that MA adult females were shorter than the national average (Steyn and Smith, 2007), and therefore, could have been a contributing factor to underweight prevalence in the current study.

Wasted infants were more prevalent in the L-SES group, and mainly boys. All boys categorised as wasted had negative length-for-age z-scores and even lower negative weight-for-age z-scores, that resulted in them defined as wasted. Interesting was that both girls identified as wasted had positive length-for-age z-scores, and although they also had negative weight-for-age z-scores, it was higher than the boys. Provincially, Du Plessis *et al.* (2016) calculated that 1.0% of their cohort aged 6 – 36 months were wasted, and Senekal *et al*. (2019) had 2.1% wasted of their cohort aged 1 - <5 years. Both these studies and the current study had a lower prevalence of wasting than the regional or national prevalence that was based on data collected between 2008 and 2017 (Sartorius *et al*., 2020). Sartorius *et al*. showed a higher prevalence of stunting at district level (Figure 2 in Sartorius *et al*., 2020) for Cape Town wherein the current study conducted its research, that might have been the reason wasting was higher at either the provincial or national averages than it was in this study.

Overweight and obesity combined had the highest prevalence of malnutrition burdens in the current study. More girls were overweight than boys and only boys were obese. Seven of these 10 infants in the current study were from the L-SES group, and 7 were between the ages of 6 – 12 months (irrespective of SES group). There were nine (9) out of the ten (10) who had exclusive breastfeeding durations between 3 – 6 months, and most started complementary feeding at the age of 6 months. There was one infant who was stunted and had a negative weight-for-age z-score, but as weight was proportional to length, the infant was reported as overweight. Senekal *et al*. (2019) reported a 5.7% prevalence of combined stunted and overweight children in a formal urban setting (which excludes informal settlements and rural areas as per this study) in the WC. Provincially, Faber *et al*. (2015) had a very low overweight/obese prevalence (5.4%) in their research similar to this study's findings compared to Senekal *et al.* (2019) at 22.8% and Du Plessis *et al.* (2016) at 21.78%. Sartorious *et al.* (2020) reported that WC had the third highest prevalence of obesity in the country after the Eastern Cape (EC) and Kwa-Zulu Natal (KZN) Provinces in 2017. Budree *et al*.'s (2017) longitudinal data resulted in a 3.3% overweight-obesity prevalence in infants aged 2 months in a predominantly MA community that increased to 9.0% at age 6 months and then decreased (4.5%) again at 12 months. Nationally, Ardington and Case (2009) reported that MA children aged 6 months to 14 years had a much higher prevalence of obesity than any of the other major population groups in SA of which double or more were from the age group 0 – 4 years, and more prevalent in urban areas than rural. Internationally, the current study's prevalence of overweight infants was the same as countries from the Middle East and North Africa, and half of that from Latin America and the Caribbean (Ghattas *et al*., 2020).

#### 5.1.2.3 MICRO- AND MACROCEPHALY

Macrocephaly had the highest prevalence of all the growth abnormalities in the current study. It differed between SES groups as MU-SES girls had a higher prevalence than the boys whereas L-SES boys had a greater prevalence of macrocephaly than the girls. Overall prevalence for microcephaly was slightly higher in girls than boys, and greater in the overall L-SES group. There was a marked difference in distribution at age 3 months and aged 6 months. At 3 months the majority on infants fell between -2 SD and +1 SD from the international standard median, and those at 6 months between -1 SD and +2 SD. Those aged 9 to 18 months aggregated between -1 SD and +1 SD.

The definition of what constitutes microcephaly was problematic in the literature. Most defined it as -2 SD from the median (WHO, 2008; Morris *et al*., 2016; Anapol Weiss, 2020) whereas a few defined it as -3 SD from the median (response to Morris *et al*., 2016). The current study used the first definition which defined it as -2 SD below the WHO norm. In Le Roux *et al*. (2020) infants aged 0 – 1.38 months (birth – 6 weeks) in the NC had above normal head circumference prevalence of 1.9% - 3.6% for boys and 6.4% - 24.8% for girls. Nicolaou *et al*. (2020) reported that SA, one of six regions of the research, had the highest consistent mean head circumference-for-age z-scores from birth to age 24 months compared to all other regions/countries included in their research, and that there was a greater prevalence of above normal head circumference measurements in this region than all others. It was evident that SA had a vastly different head circumference-for-age distribution to any of the other regions, including the overall distribution, as depicted in Nicolaou *et al*.'s (2020) Figure 3. Generally, the current study's results followed this trend except for those younger than six months, especially in the L-SES group and girls from the MU-SES group. If only infants older than 6 months were considered, they followed a similar trend as described by Rivers (2016) that stated there was a deceleration in growth rate across the first 12 months especially after 9 months and continued decelerating even more after 12 months, eventually skull development would be 90.0% of its potential adult size by age 24 months. All things considered, MA infants' skull size development older than 6 months in this study cohort was on par and above the international norm.

## 5.2 FACTORS AFFECTING ANTHROPOMETRY

For this section of the discussion, factors that were significantly associated with the anthropometric results were evaluated, and a few that showed no association, but were relevant in the literature, such as antenatal maternal smoking and drinking. This was done to highlight possible biases in the current study compared to other research. The current study excluded HIV exposed/infected infants, but it was deemed important to include some discussion as many other studies did not specify exclusion of HIV exposed/infected infants, which might have caused differences in their results compared to the current study. An important factor that was not attained in the current study was maternal height as mothers were reluctant to have their height and weight measured, but it was discussed based on adult MA female results from previous publications (Steyn *et al*., 1990; Steyn and Smith, 2007; BusinessTech South Africa, 2016) to infer possible reasons for certain growth abnormalities.

### 5.2.1 MATERNAL FACTORS

In most previous literature, maternal age was not nearly as prominent a variable in regression analysis as maternal education, but this might have been due to it being a secondary effect to other more important factors specifically tested in previous research. Maternal age has been associated with birth spacing and number of dependents (Desmond and Casale, 2017) that influenced financial resources constraints and dietary variety (Rothman *et al.*, 2018; Senekal *et al*., 2019, Sartorius *et al*., 2020) or psycho-social and cognitive development (Donal *et al*., 2018; Barnett *et al*., 2021) that were the main concerns for other publications. In the current study, maternal age was not significantly associated with maternal education, *i.e*. young mothers with a high level of education earning a higher annual income would have countered older mothers with lower levels of education but longer employment experience. This might have been the reason it was a significant variable on its own, independent of maternal education. Sartorius *et al*. (2020) had significant correlation between maternal age and stunting and obesity, whereas the current study had a very weak association for these growth abnormalities, but this might be due to the very low overall incidence of stunting in the current study compared to theirs. Maternal age significantly correlated with number of dependents, and thus, might have been the reason the latter was not a significant variable in the regression analysis as maternal age would have acted as a possible proxy for the latter. In the current study, there was no significant correlation between maternal age and the HFIAS total score which would have explained why publications focused on dietary variety and micronutrient intake might not have included maternal age as a variable in their analysis except for those mentioned previously (Oelofse *et al*., 2002; Zere and McIntyre, 2003; Faber *et al*., 2015; Du Plessis *et al*., 2016). In the current study, maternal age was a significant contributor in all regression analyses for the age-sex-adjusted z-scores for all four parameters. It was thought that maternal age was a secondary cause rather than a primary cause for association replacing variables such as number of dependents.

Maternal educational years (ME) was a prominent significant variable in most of this study's regression analyses as with many previous research results (Desmond and Casale, 2017; Budree *et al*., 2017; Ghattas *et al*., 2019; Senekal *et al*., 2019; Li *et al*., 2020; Sartorius *et al*., 2020). Black *et al*. (2013) and Senekal *et al*. (2019) stated their regression analysis showed that greater ME had a significantly protective effect on the prevalence of stunting, which correlated with this study's findings where stunting only occurred in the L-SES group. This is not to say that it was the sole reason for this prevalence. Mothers with higher ME had fewer number of dependents, birth spacing was greater and better dietary variety knowledge. Desmond and Casale (2017) showed significant correlation between catch-up growth and ME that could have signified maternal knowledge of early child monitoring (McCoy *et al*., 2014), or correct dietary intake changes, *i.e.* increased leavy vegetables + protein energy-rich food rather than calory-rich starchy foods (South African Vitamin A Consultative Group, 1996; Zere and McIntyre, 2003; Rothman *et al*., 2018; Sartorius *et al*., 2020). Higher educational attainment of mothers would have had a logical impact on income as mothers with higher educational attainment at a younger age would have had a higher income per month (or annually), yet this was offset with mothers who were older with less educational years but more experience in the work environment and promotions over time. This was evident in the current study as income (salary scale per annum) was not significantly associated with maternal age or ME, yet ME was significantly associated with medical care cost. Personal communication with mothers in especially the L-SES group indicated that mothers that were solely reliant on public health care due to financial restraints, reported home remedies for infant illnesses until such time that no professional medical care was no longer an option. This would have prolonged illness duration and affected the infant's growth as the body would have been energy-driven to combat the infection rather than physical growth. Mothers in the MU-SES group were quick (within 24 hours) to seek professional medical care. ME was also significantly correlated with the number of people that resided in a residence (identified in the current study as household occupancy). As an educational deduction, greater ME at a younger age would have increased better income prospects, allowing mothers to live with a smaller number of individuals in the residence (rent/own property or maternal parents only) as they had the monetary resources to be more financially independent. In LMICs there tended to be more individuals living in a smaller residential space to augment caregiving and financial assistance (Ghattas *et al*., 2020; Li *et al*., 2020; Adebiyi *et al*., 2021; Thurstans *et al*., 2021) as was the case in the L-SES group. This might have been the reason household occupancy in the current study was a significant contributor to length and weight related regression analyses.

Maternal height (MH) is a significant contributor in linear growth regression analyses (Black *et al*., 2013; Du Plessis *et al*., 2016; Budree *et al*., 2017; Desmond and Casale, 2017; Nicolaou *et al*., 2020; Li *et al*., 2020). Although this study did not collect MH data, inferences were made based on average MA adults' height, and the average SA adult height from previous publications (Steyn *et al*., 1990; Steyn and Smith, 2007; Du Plessis *et al*., 2016; Budree *et al*., 2017; Desmond and Casale, 2017). MA adults tended to be generally shorter than other major SA population groups that might have contributed to slightly smaller infants for gestational age (Budree *et al*., 2017). Thurstans *et al*. (2021) found that the greatest prevalence of stunting was generally between birth and 3 months, and this was evident in this study's stunting prevalence. The general trend with the MA infants were that they tended to be shorter and have LBW as was the case with Budree *et al*.'s (2017) and Barnett *et al*.'s (2021) findings. Those older than 6 months tended to aggregate above -1 SD indicating that generally MA infants would have had some type of catch-up growth or greater acceleration of growth between 3 to 6 months, which may have alluded to a slightly different starting point than the international norm. This said, if only weight or length measurements were taken at public health facilities as it has been reported in SA primary health care clinics (Kitenge and Govender, 2013; Naborn, 2016; Blaauw *et al.*, 2017; Du Plessis *et al.*, 2017), an educated deduction for mothers would have been to increase feeding for the infant to grow, and hence led to an increase in the weight-to-length proportionality observed especially around the 14 weeks postnatal point. If MA infants were shorter and/or had LBW, it might provide reason for the high overweight/obesity prevalence found especially in the L-SES group. If shorter MH were taken into consideration, it should have been explained to the mother that the child would have been shorter and weighed less than expected, and that the weight-to-length proportion was greater than it should have been which then alluded to possible future overweight or obesity health issues. Intergenerational socio-economic and -political effects within the MA community, had an impact on biological growth aspects such as stature in different communities in SA. Not only that, but also aspects of high genetic heterozygosity and geographic location. Not only was the MA population affected, but also the AD and to a lesser extend the Indian populations; creating what Sartorius *et al*. (2020) described as a "*geographic heterogeneity in malnutrition*" in SA.

Maternal smoking and drinking during the antenatal phase are described as harmful to the foetus (Blood-Siegfried and Rende, 2010; Behnka and Smith, 2013; Budree *et al.*, 2017). In this study, maternal drinking was significantly associated with jaundice at birth (Lazzaroni *et al.*, 1993). The number of participating mothers who reported that they consumed alcohol during pregnancy was low, and thus, showed no significant association with any of the growth abnormalities. That was not to say that these variables did not affect cognitive development, but as the current study's principal aim was to assess physical growth, these variables were insignificant contributors to any regression model. Personal communication with mothers during the interview process highlighted that those who did smoke during pregnancy were aware of the risks involved. Thus, they reduced the quantity of cigarettes smoked per day by more than a fifth to non-pregnancy periods. Some said that though they smoked during pregnancy, it would be only 1 per day or less than 5 per week.

Antenatal maternal health issues such as hypertension, gestational diabetes, undernutrition, chronic diarrhoea, low body mass index, and other health concerns impact foetal development (Black *et al.*, 2013; Sartorius *et al.*, 2020). This study had a few incidences of hypertension related to stunted and overweight infants, but as it was so low it had no significant effect in the regression analysis. Some of the mothers who were clinically overweight during pregnancy, had infants who were either flagged as possible overweight or obese. It was not possible to attain antenatal weight measurements as mothers were merely informed during antenatal check-ups that they gained too much weight. It was interesting that Senekal *et al*. (2019) flagged maternal obesity as a protective factor against stunting for children older than 5 years of age. A major health issue that affects antenatal and postnatal physical growth is HIV (Xiao *et al*., 2015; Morden *et al*., 2016; Mabaya *et al*., 2021). All stated that HIV infected, and uninfected but exposed infants had lower birth weights than those uninfected and not exposed. Most SA publications on growth analyses did not include the percentage of mothers and/or infants that were part of the cohort sample, except Budree *et al*. (2017) and Barnett *et al*. (2021) though these results were based on the same longitudinal Drakenstein Child Health Study. Although the HIV prevalence was much higher for the AD population group (38.0%) compared to MA (3.0%) in these studies, LBW and shorter stature prevalence were still higher with the MA infants. This clearly demonstrated that MA infants were more likely to have LBW and be shorter, even if mothers were not HIV positive. Another maternal health issues that may have impacted shorter stature and/or LBW, was maternal undernutrition in the L-SES group that would have contributed to foetal growth restrictions increasing the risk of stunting in this SES group (Black *et al*., 2013).

### 5.2.2 INFANT FACTORS

In previous studies, MA infants tended to be smaller for gestational age or had a lower birth weight (Budree *et al*., 2017) that was more than double the national average (Sartorius *et al*., 2020) although the current study's gestational age was on par with the latter publication. Budree *et al*.'s findings were not a consequence of HIV, as the HIV prevalence in their study was 3% for that specific MA community. Genetic influences and intergenerational stunting effects might have been reasons for the higher prevalence (Petersen *et al*., 2013; Montinaro *et al*., 2017; Donald *et al*., 2018) in those younger than 6 months. Hence, though they might have started shorter and weighed less, those older than 6 months were on par with the international norm. Analysis showed that gestational age was not collinear to weight status at birth (normal or not normal) which was problematic to make evidence-based inferences for MA infants, but other research based on the same population group has (Budree *et al*., 2017; Donald *et al*., 2018).

Exclusive breastfeeding duration in this study showed no significant difference for any of the age groups between the SES groups. Also, no significant difference was found between feeding method (exclusively breastfed and/or formula fed) and the SES groups overall and per age group. This was consistent with Lessa *et al*.'s (2020) results from the United Kingdom

Avon Longitudinal Study of Parents and Children, that showed no significant difference between the sociodemographic groups. Black *et al*. (2013) reported that the data used from LMICs showed no significant effect on infant length and weight, as was the case in the current study. Budree *et al*. (2017) showed a significant drop in exclusive breastfeeding between 2 to 6 months (48.0% to 8%) in the MA community, with nearly a doubling (48% to 91%) of mixed feeding in the same period. Morgen *et al*. (2021) reported that infants that were exclusively breastfed for less than 4 months were possibly more likely to be overweight than those that were exclusively breastfed for a longer period. Half of the current study's infants who were overweight or obese had 3 months of exclusive breastfeeding. Morgen *et al*. stated that based on statistical relevance it appeared that there was no significant difference between those breastfed for a shorter period of time compared to those for a longer period, which applied to the current study as the other half of overweight/obese infants were exclusively breastfed for 6 months or more. They did however caution the interpretation of their results due to biases based on recruitment of the dyad pairs and the continuation of these mother-child pairs within the longitudinal cohort. It may be argued that even though their results might not have been conclusive, it did highlight an interesting observation. What was noted was the significant contribution exclusive breastfeeding duration had on head circumference, and these results were corroborated by Nicolaou *et al*. (2020) that had the same results. A challenging observation on the duration of exclusive breastfeeding was made by Faber (2007) who noted that the introduction of formula feeding around 3 - 4 months might have a protective effect on iron deficiency or anaemia in infants as breastmilk have lower concentrations of iron than formula milk. Such iron deficiency in infants led to greater growth faltering resulting in stunted and underweight infants. WHO recommends 6 months exclusive breastfeeding, but if iron stores are depleted by age four months as per Faber (2007), and breast milk has lower concentrations than formula milk, it would stand to reason that mixed feeding from 4 months onwards would be more beneficial to linear growth. Phatlhane *et al*. (2016) showed that 39.8% of a healthy SA population had an iron deficiency (ferritin level < 30μg/L). They determined that it was more prevalent in females, and in turn may have resulted in an iron deficiency in infants at birth (Constantiaberg Haematology). It stands to reason that breastfeeding is vital for immunisation strengthening, yet addition of formula feeding from age 4 months onwards would increase iron stores assisting linear growth in addition to breast milk. Lessa *et al*. (2020) stated that it was known that mixing formula feeding with breastfeeding led to earlier cessation of breastfeeding, but this was not observed with mothers in the current study. Mixed feeding was continued to the age of 6 months, after which breast milk was less than formula milk in combination with complementary foods but remained part of the infant's dietary intake. Variation from the WHO recommendation of 6 months exclusive breastfeeding to 4 months and then after mixed feeding would be specific to a South African population to supplement iron concentration in infants and thereby aid growth.

The introduction of complementary foods at age 6 months is a vital part of the infant's diet, as it supplies micronutrient and protein energy rich foods to aid growth (Lessa *et al*., 2020; Masuke *et al*., 2021). As a norm amongst the mothers interviewed, infants were started with mashed vegetables and later introduced to infant cereals if needed to supplement dietary needs. The responses from these mothers were similar to what Oelofse *et al*. reported for their MA cohort. They also reported that calcium, magnesium, protein, vitamin A, iron, folate, and zinc dietary intake were higher in their MA cohort than the AD cohort. Sartorius *et al.* (2020) commented that low income resulted in limited dietary variety which translated into cheaper food with high calory content (bread and/maize products) but very little essential micronutrients from fresh fruit and vegetables. This phenomenon might have been the reason overweight/obesity were more prevalent in the L-SES group and in those older than 6 months in the current study. The greatest micronutrient deficiencies have been demonstrated in Africa and on average have been higher than globally, except in Asia (Black *et al*., 2013). As per the introduction of supplementary vitamin A booster drops for infant aged 6 – 59 months (SA policy) that started in 2002 due to national research that highlighted the effects this deficiency would cause to growth in young children, other micronutrient (such as iron) booster drops can be made available in a similar fashion. Two cases in the current study of extreme obesity (> +4) were infants who had solids introduced at 1 month and 4 months old, to the extent that both were only consuming solids by age 6 months, and very little formula milk, but no breast milk, at this age.

### 5.2.3 SOCIO-DEMOGRAPHIC AND -ECONOMIC FACTORS

All participants had a water source and sanitation facilities on their residential property. Zere and McIntyre (2003) reported WC had the highest percentage of people with access to these two variables on their residential property than anywhere else in the country at the time of their data collection. They also reported that WC had the second lowest rural population (after Gauteng Province or GP) in SA, and the second lowest poor rates (again after GP) in SA. This was corroborated by Faber *et al*. (2015). They noted that of the four regions they surveyed, urban WC had the lowest levels for receiving the SA government child grant. South African researchers had previously reported that the AD population group on average were poorer than

MA yet anthropometrically their development was better than MA (Budree *et al*., 2017; Faber *et al*., 2015; Donald *et al*., 2018; Hill *et al*., 2020). Budree *et al*. showed that although MA has less unemployment and greater income than AD, at all points of data collection, AD weight and length z-scores were higher than MA, and the greatest prevalence of stunting and underweight was in MA, that indicated that AD had a greater starting point than MA. This alludes to additional factor(s) other than socio-economic status that affects ante- and postnatal growth of MA.

More mothers worked in the MU-SES group than the L-SES group in this study, and they tended to have higher incomes that allowed them to provide greater dietary variety, and immediate medical care. Based on this, lower infant illness prevalence was experienced by the MU-SES infants than the L-SES infants. Duration of illnesses were also shorter in the former than the latter that ultimately would have impacted physical growth (Labadarios and Steyn, 2005; Akachi and Canning, 2007; Shisana *et al*., 2013; Statistics South Africa, 2017b; Isaacs-Long *et al*., 2017). SES as a known risk factor for LBW and is significantly associated with stunting/underweight/wasting, not only in SA but globally, was a result of income levels and most probably the reason it showed significant contribution to the length-for-age regression analysis (Said-Mohamed *et al*., 2015; Monyeki *et al*., 2015; Ghattas *et al*., 2020; Li *et al*., 2020; Thurstans *et al*., 2021). Neither maternal age nor maternal education was associated with income levels (salary scale), and thus, the latter variable could not be said to be a result or influenced by the first two variables, that explained the significant contribution of all three variables for the length-for-age regression analysis. Zere and McIntyre (2003) stated that SES, demography, and geography highly influenced the prevalence of the double burden of malnutrition, and Sartorius *et al*. (2020) corroborated this with extensive research outputs at a district level from west to east and north to south in SA. The latter termed it "*Geographic Heterogeneity in Malnutrition*" and declared it a "*Public Health Conundrum*".

It was expected that low HFIAS total scores (indicating food insecurity) would possibly significantly contribute to especially the length and/or weight regression analysis, but it did not. This occurrence was in accordance with the results from Labadarios *et al*. (2005) (the National Food Consumption Survey) and Senekal *et al.* (2019); both reported that shortage of food was not a significant predictor for growth abnormalities, but Senekal cautioned this interpretation as they sampled the two wealthiest provinces in SA, namely GP and WC, of which one was sampled by the current study as well.

Income levels (salary scale in this study) and household occupancy (as discussed previously) were the only socio-economic factors that significantly contributed to the length- and/or weight-for-age regression analyses. It was not to say that other socio-economic factors did not contribute to the stunting, wasting, overweight and obesity prevalence in the region of the current study (City of Cape Town), or at a provincial or national level, rather that the conditions of living between the SES groups were not as vastly different to significantly contribute to the regression analysis. Ablution facilities (flushed toilets vs bucket toilets), water source (on residential property vs communal taps/collecting water from rivers), distance travelled to health care facilities (urban formal vs urban informal/rural), cooking facilities (electricity vs paraffin) and residential structure (formal versus informal), were factors previously associated with growth faltering (Zere and McIntyre, 2003; Faber *et al*., 2015; McCoy *et al*., 2016; Desmond and Casale, 2017; Donald *et al*., 2018; Senekal *et al*., 2019; Satorius *et al*., 2020), but these variable comparatives were not possible in the current study as none of the participants reported the latter of the comparatives. Therefore, it would have explained the low percentage (8.3% to 24.6%) variation the regression models presented in the current study's cohort, and possibly the reason that most growth abnormalities had very low prevalence compared to previous regional, provincial, national, and international research.

IN SUMMARY:

Nutritional anthropometry and determinants of health have been researched for centuries as the global population has expanded, developed, and grown. Socio-demographic evolution, socio-economic inequalities, aetiology, and epidemiology are constantly fluctuating in the modern world and Science must evolve with it. From the first ever growth chart in the 18$^{th}$ century (*cited in* Hedström, 1969) to the WHO MGRS 2006 (De Onis *et al*., 2006), many variations of child growth charts have existed. Research was the key in these adaptations of previous growth standards and/or references. If growth charts are used to determine the well-being of a child, and the population at large, the data used to construct such growth charts should to some degree incorporate ancestral genealogy, geographic location (high vs low altitude; coastal vs inland), and possible intergenerational effects or secular trends. Rather than only focus on how a child should grow, consideration should be given to how a child does grow and the factors that affect this physical development.

The WHO MGRS child growth standards were designed with the belief that all children, irrespective of ethnicity (ancestral genealogy), should grow at the same rate if they were healthy single births, born between 37 – 42 gestational weeks, were exclusively breastfed for at least 6 months, generally had no intrauterine stressors such as maternal drinking or smoking, and maternal chronic diseases/illness. These are factors that are manageable for mothers as a choice. What is not manageable are various intergenerational effects. For example, environmental influences may have intergenerationally altered growth rate to compensate for mortality at an early age (Walker *et al*., 2006). Maternal height, which is not determined by the mother, may cause intrauterine constriction for foetal growth and hence, the infant is shorter in stature or has a lower birth weight than prescribed by the WHO MGRS 2006 growth standard. Mothers who have a natural iron deficiency, and may not be aware, also affects the 'iron store' infants are born with and hence, can affect growth.

It is known that in LMICs, as SA is, lack of nutrition is a major concern for stunting, underweight and wasting. But what about micronutrient deficiency even if the child does not lack food availability? As mentioned in the literature review of this thesis (chapter 2, page 16), Steckel (1995; 2008) ascribed resultant linear growth to the access individuals have to resources such as nutrient-rich food which was offset by the body's metabolic requirements either as physical activity or an immune response to illness or disease. If inadequate micronutrients are available in the infant's diet, then the infancy-childhood transitional age (ICT) is delayed, which means no increase of growth hormone insulin-like growth factor 1 (IGF1) for bone and cartilage growth, possibly resulting in infants not reaching their full height potential (Hochberg, 2009; Gawlik *et al*., 2011; Hochberg 2011; Perera and Herbstman, 2011; German *et al*., 2015). Knowing that an infant's iron store is nearly depleted by age 4 months, and that formula feeding helps restore said iron concentrations, calls into question the reliability of the recommendations for exclusive breastfeeding until the infant is 6 months of age. Combined breastmilk and formula milk could improve growth rates of infants from the age of 4 months when their natural iron stores are nearly depleted. Introducing complementary foods very early (prior to six months) in an infant's diet may lead to overweight and obesity later in life. This may be due to the food not containing enough of the essential nutrients needed for growth that is found in either breastmilk or formula milk or overfeeding may occur. This in turn increases the child's future risk of non-communicable diseases such as type 2 diabetes and hypertension. Hence, creating further strain on health in the next generation's childbearing mothers, and hence, continues the burden of malnutrition intergenerationally.

Considering these factors affecting children's physical growth, it cannot be said that 'one size fits all' when developing growth charts; certain concessions must be made. Hence, scientists around the world tested the applicability of the WHO child growth standards for specific countries or regions. As discussed in the literature review of this thesis, there are variations from the WHO growth standard, whether it be in a socio-economically developed region or in a developing region of the world. Inokuchi *et al*. (2018) states that the WHO child growth standard overestimates stunting and underweight, yet only small differences were found comparing weight-for-length/height with a national growth reference. Tian *et al*. (2019) reported that both the WHO standards and a national standard should be used for different parameters of physical growth.

Growth abnormalities in the current study were significantly below the regional, provincial, national, and international prevalence for a low- and middle-income country, that may have been resultant of the small sample size, the specific population group, socio-economic and -demographic conditions, and/or the inclusion and exclusion criteria. Boys had a greater prevalence of stunting versus girls as cited in the literature (Wamani *et al*., 2007), and in this study was only observed in the L-SES group. The SADHS reported that stunting prevalence rates of between 13.0% to 24.0% were found in the mid to upper wealth quantiles. Therefore, though stunting only occurred in the L-SES group in this study, stunting does occur in the mid to upper wealth quintiles nonetheless despite the results from this research. These specific results could merely be indicative of the sample cohort in the MU-SES group. Very tall infants were found in both SES groups with greater prevalence amongst girls. Underweight and wasting was more prevalent in boys in the L-SES group. Overweight/obesity prevalence was also greater in the L-SES group for both girls and boys, and girls in general tended to have higher weight-for-length z-scores than boys. The study cohort's head circumference measurement distribution for those older than 6 months were above the international norm, and the highest percentage growth abnormality was for macrocephaly.

Maternal factors that significantly contributed to the variation within the cohort were maternal age and maternal education. Although maternal height was not collected, inferences could be made based on previous research regarding average maternal height in the MA adult population, specific to the region and nationally, and was included in the discussion as previous research reported its significance for shorter stature and LBW. Infant factors that were significant contributors were gestational age (weeks), weight status at birth (normal vs not normal), exclusive breastfeeding duration, and infant age when complementary food was introduced as part of the infant's dietary intake. SES factors that contributed to the variation in the regression analysis were income levels (salary scale) and number of individuals who resided permanently within the household (household occupancy). HFIAS total scores were not significant between the SES groups and had no significant contribution to any of the regression analysis as noted by previous national research.

Significantly low variation was represented by the regression models that may have been resultant due to limitations and biases in the current study. This included a small sample size, focus on a specific population group, urban formal setting, second wealthiest province nationally, no chronic illnesses or diseases, no child that was ill up to 14 days prior to measurements taken, very low prevalence of maternal drinking during pregnancy, and no psychoactive drug use (not including alcohol). Despite these limitations and biases, the study's cohort was representative of a healthy MA population. Just over 42.0% of the cohort were younger than 6 months and the general aggregate distribution of anthropometric measurements amongst these infants were negative and thus below the WHO growth norm. As Desmond and Casale (2017) so eloquently stated "*they might generally just be slow starters*", with MA infants older than 6 months in the current study cohort aligned with the WHO norm. It is not to say that growth faltering does not occur post 18 months for MA infants, but as Thurstans *et al*. (2021) noted the "*peak incidence*" or simply put the highest percentage of wasting and stunting is found amongst infants between 0 - 3 months of age. Overweight and obesity prevalence may have been the resultant effect of early cessation of exclusive breastfeeding and/or early (less than 6 months) introduction of complementary food and/or micronutrient deficiencies due to limited nutrient-rich dietary intake because of financial constraints. Growth faltering have many contributing factors, and as Faber *et al*. (2015) stated national surveys must be complemented by regional studies that was corroborated by the research outputs from Sartorius *et al*. (2020) that showed a national gradient from the west coast (greatest prevalence of wasting) to the east coast (greatest prevalence of overweight/obesity) in SA, coining the phrases "*Geographic Heterogeneity in Malnutrition*" creating a "*Public Health Conundrum*".

## 5.3 FIELD WORK, STUDY LIMITATIONS/BIASES AND FUTURE WORK

### 5.3.1 FIELD WORK

At all three research locations, the medical and administrative staff were extremely helpful. Most public health facilities have limited space for their own staff, but they made special concessions for me to have a private space to conduct interviews and do measurements. Both staff and members of the public were interested in the research I was doing and indicated that they felt good knowing they were not a forgotten people. Fortunately, I was able to fluently communicate with all possible participants that were approached. At the location for the L-SES group, most mothers preferred to speak Afrikaans or an English dialect common amongst MA individuals in Cape Town. I had the advantage of growing up in a similar community in Cape Town and was conscience of how I addressed probable and recruited participants. On a few occasions mothers were wary, although they already consented to participate, and their emotional distress was palpable by their infant. Therefore, I decided to do the interview first so both the mother and the infant could settle down, and to build trust with the infant prior to the anthropometric measurements.

### 5.3.2 STUDY LIMITATIONS AND BIASES

The fieldwork involved in data collection for this study had many limitations. One of the greatest limitation to this study was the low number of successfully recruited dyad pairs due to the outbreak of the "severe acute respiratory syndrome coronavirus 2" (SARS-CoV-2) that caused the global Covid-19 pandemic (https://www.who.int/diseases/novel-coronavirus-2019). A National State of Disaster was declared in SA, and all non-essential medical staff were prohibited from entering government health facilities including the primary health care facilities we had permission and ethical clearance to do research at. As a result of the 'lockdown' proscriptions, many businesses were closed during this time, and many families were severely financially affected. Unable to collect nutritional anthropometry and information on determinants of health, it was decided that data collection post-lockdown would have considerably affected statistical findings with the pre-lockdown data, that would have created further bias within the study cohort. The MU-SES study cohort was also very small due to parents who did not want to partake, both at Diep River Clinic and MeloMed Private Hospital, Tokai.

It was interesting to note that mothers and infants who were accompanied by fathers, were far more reluctant to participate than mothers who were unaccompanied. Many days, there would be 5 – 6 qualifying dyad pairs, but only 1 would consent. Though not overtly stated, many parents would have allowed infants to be measured, but were extremely reluctant to complete the questionnaires even though it was explained that I would complete the form as they answered. I understood that for some it felt like an invasion of their privacy by a stranger.

One important exclusion criteria in this study was that of HIV+ mothers and infants, even if the mother was on antiretroviral medication as its been noted in medical research that infant linear growth is affected (Morden *et al*., 2016). Most of the comparative publications cited in this thesis did not specify whether or not HIV infected and HIV uninfected but exposed infants were excluded/included in their infant cohort, and might have increased prevalence of stunting and underweight in their findings. Publications such as Budree *et al*. (2017) and Barnett *et al*. (2021) were the only ones who stated the inclusion of HIV+ participants and the prevalence within the community.

This research was focused on the MA population as limited research had been done, except for the Oelofse *et al*. (2002), Budree *et al*. (2017) and Donald *et al*. (2018) who separated their population groups into MA and AD, on a healthy MA infant cohort with no chronic diseases and/ or illnesses. Other publications separated boys and girls but not population groups (Le Roux *et al*., 2020; Barnett *et al*., 2021). This made comparatives convoluted. Notwithstanding these biases, inferences could be made regarding MA infant growth spanning the last two decades that will guide future research.

### 5.3.3 FUTURE WORK

It is recommended that research pertaining to MA infants aged 0 – 6 months be continued for both a healthy cohort where exclusion criteria is scripted as in this study, and then comparative research should be done with infants suffering chronic disease/illnesses. This would help the implementation of research-driven policy such as the free postnatal vitamin A booster drops infants receive from 6 months to 59 months when they are due for immunisations and check-ups (every 6 months after 18 months of age) at any government primary health care facility.

In addition, scientists should stress the importance of taking all anthropometric measurements (length, weight, and head circumference), and why it should be plotted in the Road-to-Health booklet. The Road-to-Health booklet is a phenomenal tool that should be used effectively, as its financial costs to government is not yet offset by palpable rewards for the SA population at present. With this type of research-driven policy, educational programmes and in-service training of primary health care professionals would improve and increase focus on anthropometry as is done currently for HIV and tuberculosis testing, through the process of understanding the importance of the growth charts and how to interpret anthropometry correctly and successfully. One example is the reason plotting weight-for-length-for-age is vital in identifying growth abnormalities in infants earlier than 12 months or even 24 months, and possibly decreasing the burden of overweight/obesity in the country and hence, alleviating financial strain on the government. In turn, funds can be made available for government research units focused on child health as set out by the South African Department of Health's "*Strategic Plan 2020/21 – 2024/25*", the South African "*National Development Plan 2030 section 27*", the United Nations' "*Sustainable Development Goal 3: Good Health and Well-being 2030*", and "*CAP-2030 (Children in All Policies 2030)*" implementing the WHO-UNICEF-*Lancet* Commission's recommendations.

# CHAPTER 6: CONCLUSION

This research provides baseline data for healthy, full-term 0 – 18-month-old MA infants that can be used in different spheres of public health. The evaluation of the data showed that although most of this study's cohort were within the WHO standard norm range (-2 SD to +2 SD from the median) for all the age-standardised z-scores, there may be reason to suspect a slight negative (below the WHO standard norm) for infants younger than 6 months. This is turn may be evidence for the causation of overweight and obesity in early infant and childhood phases. The prevalence of stunting in SA children under five years has been reported as high (SADHS reported prevalence rate of 27.8% in 2016), yet the stunting prevalence amongst this study's healthy MA cohort was very low. This dissimilarity may be indicative of the inclusion of children with health issues in estimating the national prevalence rates. It is also suggested by this study that a national head circumference growth reference would be best suited to evaluate cranial growth as head circumference measures in MA infants older than six months indicated that SA infants were above the WHO growth standard norm.

As with previous South African research, maternal age, maternal education, age complementary food is introduced, and to a lesser degree, exclusive breastfeeding duration were significantly associated with linear growth. Although household occupancy or the number of people residing in a single residence is significantly associated with length, weight, and weight-for-height, it is suggested that this might be a secondary effect due to maternal age and education. Similarly, salary scale can also be associated with maternal age and education. Due to the absence of maternal height data (not collected due to the reluctance of mothers), evaluation of previous literature concerning this aspect may explain why the percentage variance in the regression models were low.

These findings may not be the same across the country or for all population groups in SA, but it does attest that there is probable cause to further investigate healthy MA infants across the country and better understand factors affecting their physical growth. Expanding on research done on African descendent infants across the country, this would help in achieving a national understanding of SA infant growth. It is within these two population groups that stunting, wasting, and overweight/obesity prevalence are higher than other ancestral groups in SA (Ardington and Case, 2009). It could be speculated that the growth differences observed in this study and other research of MA infants may have been the effect socio-economic disparity, due to regimented socio-political conditions in the apartheid government, had on previous MA generations from which these infants in this study stem. These past, and persisting currently, socio-economic disparities may have resulted in a phenotypic expression of shorter stature in response environmental conditions. These intergenerational effects of environmental conditions on linear growth may explain the "*spatial-temporal trends*" observed by Sartorius *et al*. (2020) who established a gradient of growth abnormalities in SA from west (greatest stunting prevalence) largest proportion of South African MA population group in Western Cape and Northern Cape Provinces) to east (greatest overweight/obesity prevalence; largest proportion of South African AD population group in Limpopo, Mpumalanga, Kwa-Zulu Natal, Eastern Cape Provinces) as Figure 2.1 (page 20) shows. As Desmond and Casale (2017) stated: "*we might just be slow starters*". It is therefore important for primary healthcare professionals to record both length and weight (not just weight) measurements to enable them to plot the weight-for-length at a specific age, and hence, better assess the nutritional status of a child. Lacking one of these measurements, especially length, may lead to misinterpretation of nutrition status.

If healthy, full-term MA infants younger than 6 months deviate in length and weight below the WHO growth standard norm, this may suggest a possible causal mechanism for the high prevalence rates of adult-onset NCDs in MA. Overweight and obesity prevalence rates are very high (nearly 70.0% of MA females older than 15 years) within the MA population group of South Africa and may be a resultant effect of incorrect early life nutritional status diagnosis (Statistics South Africa, 2017). As stated previously, MA adults have the second highest type 2 diabetes prevalence rate, second only to the South African Indian population group (Pheiffer *et al*., 2021), and hypertension prevalence was highest in MA female adults in 2008 (Ardington and Case, 2009).

In conclusion this thesis' findings suggest a different growth trajectory in healthy MA infants between birth and 6 months. As stated before, research-driven policy implementation would assist in the attainment of the goals set out by the National Development Plan 2030 section 27, the United Nations' Sustainable Development Goal 3: Good Health and Well-being 2030, and CAP-2030 (Children in All Policies 2030). Policy progress is slow according to Sartorius *et al*. (2020), and we might just be slow starters as Desmond and Casale (2017) voiced, but if not addressed by determining appropriate growth trajectories for healthy SA infants at important growth phases (*i.e*. ICT), the triple-burden of malnutrition will persist and so too the high prevalence rates of non-communicable diseases in adulthood.

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# APPENDICES

## Appendix A: Conference and publication acceptance letters.

AAPA 2021 abstract acceptance Inbox

aapa2021@berkeley.edu 2021/01/03
to me, aapa2021

Dear Liesl M. Arendse,

Happy New Year!

On behalf of the Program Committee for the 2021 AAPA annual meeting, I am pleased to inform you that your abstract:

**Growth analysis of South African Mixed Ancestry infants**

has been accepted for the AAPA's virtual conference that will run from April 7 - 28, 2021

At this time, your contributed abstract has NOT yet been assigned to a particular session or date--we use a two-stage process, with the review process followed by scheduling. Abstracts that have been accepted and included in invited symposia will be scheduled for those symposia.

The Program Committee will be working throughout January to assign presentations to sessions, dates, times, and formats. We will notify you via e-mail with specific schedule information as soon as we complete that process (early February).

As you plan your schedule for the next few months, please keep in mind that all presentations will need to be uploaded in March. In February, I will send out detailed instructions.

Thank you for submitting your research for the AAPA 2021 conference. I look forward to seeing you online!

Sincerely,

Leslea Hlusko
AAPA Vice President (Scientific Program Chair)
aapa2021@berkeley.edu

**Figure A.1: Abstract acceptance letter for the 90th Annual Meeting of the American Association of Physical Anthropologists (AAPA) 2021.**

Your Submission Inbox

SAJCH 2021/04/21
to me

You are being carbon copied ("cc:'d") on an e-mail "To" "Victoria Gibbon" victoria.gibbon@uct.ac.za
CC: "Liesl M. Arendse" lieslarendse7@gmail.com, "Desiré Brits" desire.brits@wits.ac.za, "Estelle V. Lambert" vicki.lambert@uct.ac.za

Ref.: SAJCH01805R1
Is the World Health Organization's multicentre child growth standard an appropriate growth reference for assessing optimal growth of South African Mixed Ancestry children?
South African Journal of Child Health

Dear Prof Gibbon,

We are pleased to let you know that your manuscript has now been accepted for publication in South African Journal of Child Health.

Please find payment form attached herewith. As soon as proof of payment and the completed form have been received, we will send your article into production. (Please note that we are unable to process American Express card payments). Please send proof of payment to claudian@samedical.org

Nearer the date of publication you will receive page proofs from the copy editor, please check these carefully for errors.

Thank you for submitting your work to the journal.

Best wishes

John Pettifor, MBBCh; PhD
Editor In Chief
South African Journal of Child Health

**Figure A.2: Manuscript acceptance letter for the South African Journal of Child Health (SAJCH).**

**Appendix B: Accepted abstract for the South African Journal of Child Health (SAJCH).**

(*Please note that only the abstract is available as the article is still in print.*)

**Is the World Health Organization's multicentre child growth standard an appropriate growth reference for assessing optimal growth of South African Mixed Ancestry children?**

**Arendse, Liesl M. (MSc) [(1)]; Brits, Desiré (PhD) [(2)]; Lambert, Estelle V. (PhD) [(1)(3)]; Gibbon, Victoria E. (PhD) [(1)]**

[(1)] Department of Human Biology, Faculty of Health Sciences, University of Cape Town, Cape Town
[(2)] Human Variation and Identification Research Unit, School of Anatomical Sciences, Medical School, University of Witwatersrand, Johannesburg
[(3)] UCT Research Centre for Health through Physical Activity, Lifestyle and Sport (HPALS), Department of Human Biology, Faculty of Health Sciences, University of Cape Town

**Corresponding author:**

Victoria Gibbon, Room 5.06, 5th Floor, Department of Human Biology, Anatomy Building, Faculty of Health Sciences, University of Cape Town, Anzio Road, Cape Town 7935 South Africa
Tel: 021 650 4431 or 063 652 3439
Email: Victoria.gibbon@uct.ac.za

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**Conflict of interest**

The authors hereby acknowledge that there is no conflict of interest regarding this publication.

**AUTHOR DECLARATION**

We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all of us.

We confirm that we have given due consideration to the protection of intellectual property associated with this work and that there are no impediments to publication, including the timing of publication, with respect to intellectual property. In so doing we confirm that we have followed the regulations of our institutions concerning intellectual property.

We further confirm that no aspect of the work covered in this manuscript has involved either experimental animals or human patients.

We understand that the Corresponding Author is the sole contact for the Editorial process (including Editorial Manager and direct communications with the office). He/she is responsible for communicating with the other authors about progress, submissions of revisions and final approval of proofs. We confirm that we have provided a current, correct email address which is accessible by the Corresponding Author and which has been configured to accept email from: Victoria.Gibbon@uct.ac.za

Signed by all authors as follows:

Liesl Arendse

Desiré Brits

Estelle V. Lambert

Victoria E. Gibbon

# <u>Manuscript:</u>

**Is the World Health Organization's multicentre child growth standard an appropriate growth reference for assessing optimal growth of South African Mixed Ancestry children?**


**Abstract**

In South Africa (SA), it has been estimated that one third of boys and 25% of girls under the age of five are stunted according to the World Health Organization's (WHO) Multicentre Growth Reference Study. In the last decade, research in both developed and developing countries have shown that the international growth standard overestimates stunting and/or wasting when compared to population-specific growth references. Population-specific growth references typically incorporate both genetic and environmental factors and can therefore better inform public health by identifying children who may be at risk for malnutrition, or who may be ill. Using the universal growth standard in SA may not be accurately assessing growth. In this article both environmental and genetic factors, and their influence on growth are reviewed. These points are illustrated through a brief history of the peopling of SA with an understanding of the socio-economic and political climate, past and present. We discuss the uniqueness of certain population groups in SA, with contributions from some of the shortest peoples in the world and a history of socio-political inequities, which may mean that children from certain population groups who are perfectly healthy would underperform using the universal growth standard. Therefore, we suggest that a local population specific growth reference would serve to better inform public health policies, to address childhood health equity and physical developmental pathways to adult health risk status.



*KEYWORDS:* Growth, growth reference, growth charts, Multicentre Growth Reference Study (MGRS), stature, nutrition, socio-economic status

**Appendix C: Ethics approval letter and permission letters for research facilities.**

**UNIVERSITY OF CAPE TOWN**
**Faculty of Health Sciences**
**Human Research Ethics Committee**

**Room E53-46 Old Main Building**
**Groote Schuur Hospital**
**Observatory 7925**
**Telephone** [021] 406 6492
**Email:** sumayah.ariefdien@uct.ac.za
**Website:** www.health.uct.ac.za/fhs/research/humanethics/forms

22 February 2019

**HREC REF: 075/2019**

**Dr V Gibbon**
Clinical Anatomy and Biological Anthropology
Anatomy Building, Level 5, Room 5.14
FHS

Dear Dr Gibbon

**PROJECT TITLE: GROWTH CURVE ANALYSIS AND NEW STANDARD DEVELOPMENT FOR SOUTH AFRICAN CHILDREN AGED 0-3 YEARS OF MIXED ANCESTRY ('COLOURED') PHD CANDIDATE - MS L ARENDSE**

Thank you for submitting your study to the Faculty of Health Sciences Human Research Ethics Committee (HREC) for review.

It is a pleasure to inform you that the HREC has **formally approved** the above-mentioned study.

**Approval is granted for one year until the 28 February 2020.**

Please correct the spelling of the HREC contact email in the informed consent form.

Please submit a progress form, using the standardised Annual Report Form if the study continues beyond the approval period. Please submit a Standard Closure form if the study is completed within the approval period.
(Forms can be found on our website: www.health.uct.ac.za/fhs/research/humanethics/forms)

***We acknowledge that the student: Ms Liesl Arendse will also be involved in this study.***

**Please quote the HREC REF in all your correspondence.**

Please note that the ongoing ethical conduct of the study remains the responsibility of the principal investigator.

Please note that for all studies approved by the HREC, the principal investigator **must** obtain appropriate institutional approval, where necessary, before the research may occur.

Yours sincerely

pp LBurgess

**PROFESSOR M BLOCKMAN**
**CHAIRPERSON, FHS HUMAN RESEARCH ETHICS COMMITTEE**

Federal Wide Assurance Number: FWA00001637.

**Figure C.1: University of Cape Town's Human Research Ethics Committee's ethics approval letter.**

Western Cape Government
Health

**Health Impact Assessment**
**Health Research sub-directorate**
Health.Research@westerncape.gov.za
tel: +27 21 483 0866; fax: +27 21 483 9895
5th Floor, Norton Rose House, 8 Riebeek Street, Cape Town, 8001
www.capegateway.gov.za)

REFERENCE: WC_201905_037
ENQUIRIES: Dr Sabela Petros

**University Of Cape Town**

**Anzio Road**

**Observatory**

**Cape Town**

**7925**

For attention: Dr Victoria Gibbon, Ms Liesl Margo Arendse, Dr Desirè Brits, Prof Estelle V Lambert

Re: **Growth curve analysis and new standard development for South African children aged 0 - 3 years of Mixed Ancestry ('Coloured')**

Thank you for submitting your proposal to undertake the above-mentioned study. We are pleased to inform you that the department has granted you approval for your research.

Please contact the following person to assist you with any further enquiries in accessing the following sites:

| | | |
|---|---|---|
| **Bishop Lavis CDC** | **Dr Mumtaz Abbas** | **021 927 1147** |

Kindly ensure that the following are adhered to:

1. Arrangements can be made with managers, providing that normal activities at requested facilities are not interrupted.
2. By being granted access to provincial health facilities, you are expressing consent to provide the department with an electronic copy of the final feedback (**annexure 9**) within six months of completion of your project. This can be submitted to the provincial Research Co-ordinator (Health.Research@westerncape.gov.za).
3. In the event where the research project goes beyond the *estimated completion* date which was submitted, researchers are expected to complete and submit a progress report (**Annexure 8**) to the provincial Research Co-ordinator (Health.Research@westerncape.gov.za).
4. The reference number above should be quoted in all future correspondence.

Yours sincerely

Dr Melvin Moodley
Director: Health Impact Assessment
26 JUN 2019

**DR M MOODLEY**

**DIRECTOR: HEALTH IMPACT ASSESSMENT**

**Figure C.2: Permission letter to conduct research at Bishop Lavis Clinic, Cape Town, South Africa.**

CITY OF CAPE TOWN
ISIXEKO SASEKAPA
STAD KAAPSTAD

**CITY HEALTH**

**Dr Natacha Berkowitz**
Epidemiologist: City Health

**T**: 021 400 6864 **F**: 021 421 4894
**E**: Natacha.Berkowitz@capetown.gov.za

Ref: 24486

2019-06-19

**RE: Growth curve analysis and new standard development for South African children aged 0 – 3 years of Mixed Ancestry ('Coloured')**

Dear Victoria Gibbon

Your research request has been approved as per your protocol. Please refer to the subsequent pages for the approval of any facilities or focus areas requested. Approval comments on any proposed impact on City Health resources are also provided.

Mitchells Plain & Southern:

Contact Person: Mrs Soraya Elloker (Area South Manager)

Tel/Cell: 021 400 3983/084 222 1478

Email: Soraya.Elloker@capetown.gov.za

**Please note the following:**

1. All individual patient information obtained must be kept confidential.
2. Access to the clinic and its patients must be arranged with the relevant Manager such that normal activities are not disrupted.
3. A copy of the final report must be uploaded to http://web1.capetown.gov.za/web1/mars/ProjectClosure/UploadReport/0/8162, within 6 months of its completion and feedback must also be given to the clinics involved.
4. Your project has been given an ID Number (8162). Please use this in any future correspondence with us.
5. No monetary incentives to be paid to clients on the City Health premises
6. If this research gives rise to a publication , please submit a draft before publication for City Health comment and include a disclaimer in the publication that "the research findings and recommendations do not represent an official view of the City of Cape Town "

Thank you for your co-operation and please contact me if you require any further information or assistance.

Kind Regards
Dr Natacha Berkowitz Epidemiologist: City Health

**CIVIC CENTRE IZIKI LOLUNTU BURGERSENTRUM**
HERTZOG BOULEVARD CAPE TOWN 8001 PO BOX 2815 CAPETOWN 8000
www.capetown.gov.za

Page 1 of 3

Making progress possible. Together.

**Figure C.3: City of Cape Town permission letter to conduct research at Diep River Clinic, Cape Town, South Africa.**

## Appendix D: Informed consent form and information pamphlet.

**Project title:**
**Growth curve analysis and new standard development for South African children aged 0 – 3 years of Mixed Ancestry ('Coloured')**

Dear Parent / Legal Guardian / Caregiver,

There is no data to chart the growth of Coloured children in South Africa; therefore, they are compared against European or African standards produced by the World Health Organisation. For my PhD, at the University of Cape Town, I want to examine and produce a growth and development standard for children aged 0-3 years specific to the South African Coloured population. This is important so that we can help them reach their full height potential and monitor their health accurately. As a member of this community, I want to help improve our children's development.

**Are there any risks to your child's participation?**
No. None of the measurements will put them at risk, or cause them physical harm.

**Do you have to participate?**
No. It's your free choice to participate. There'll be no adverse consequences if you say no. Also, if you do decide to participate, but you are uncomfortable and unhappy, feel free to stop participating at any time.

**Is it confidential?**
Yes, you and your baby's name will be kept confidential. No names will be used. You'll get a specific participant identification number (PID) that only I will know.

**What does participation include?**
**25-30 minutes to answer some questions** about your home environment, food security and medical history, I'll help you complete these, while you wait to see the nursing staff.

**5-10 minutes for basic measurements:** weight, height and head measurements of your child. Each measurement must be taken three times. If you are the birth mother, we would like to take your height and weight measurement, to see if there is an association between mother and child's height and weight.

I may need your help during the measurements of your son/daughter so they feel comfortable, and it would be good if you would talk to your child to make them comfortable. The questionnaires, which I'll help you complete, will be done in private while you wait to see the nursing staff. I'll try my best not to delay you.

**What are the benefits of participating?**
There is no direct benefit to you or your child for taking part in this study. However, this study will help us to better understand the physical growth of children from the Coloured community.

**Questions?**
If you have any questions related to the ethics of this study, please contact Prof Marc Blockman, Chairperson of the University of Cape Town's Human Research Ethics Committee (HREC), at (021) 406 6496 (Tel.), (021) 448 1989 (Fax) or marck.blockman@uct.ac.za.

Please do not hesitate asking me to clarify anything or for help with the consent form. I'm here to help. If you are willing to participate, please read and sign the consent form at the back and we will start with the questions.

Thank you for your time and attention.

Kind regards
Liesl Arendse
Student Researcher: PhD in Anatomy
University of Cape Town

**Figure D.1: Caregiver/mother/legal guardian information pamphlet.**

**Project title:**

**Growth curve analysis and new standard development for South African children aged 0 – 3 years of Mixed Ancestry ('Coloured')**


| | |
|---|---|
| Student Investigator | **Ms. Liesl Arendse**, University of Cape Town, Department of Human Biology, Division of Clinical Anatomy and Biological Anthropology, Observatory, Cape Town<br>E-mail: arnlie002@myuct.ac.za |
| Principal Investigator | **Dr. Victoria Gibbon**, University of Cape Town, Department of Human Biology, Division of Clinical Anatomy and Biological Anthropology, Observatory, Cape Town.<br>E-mail: victoria.gibbon@uct.ac.za |
| Co-supervisors | **Dr. Desiré Brits**, University of Witwatersrand, Medical School, School of Anatomical Sciences, Parktown, Johannesburg<br>E-mail: desire.brits@wits.ac.za |
| | **Professor Estelle (Vicki) Lambert**, University of Cape Town, Department of Human Biology, UCT/MRC Research Unit for Exercise Science and Sports Medicine, Sports Science Institute of South Africa, Newlands, Cape Town<br>E-mail: vicki.lambert@uct.ac.za |


**Informed consent for child's participation in the study**

I agree to participate in this study. The goals and methods of the study have been explained clearly to me. I understand that the study will involve completing questionnaires, being interviewed, and possibly having measurements taken from my son/daughter, and possibly myself. I understand that my child's / our data will remain strictly confidential, except to the researchers involved. I understand that I have the Right to refuse to participate in the study.

I agree to participate in the study on condition that:

1. I can withdraw participation from the study at any time voluntarily and that no adverse consequences will follow on withdrawal from the study.
2. The University of the Cape Town's Human Ethics Committee has approved the study protocol and procedures.
3. All results will be treated with the strictest confidentiality.
4. Only group results, and not my child's individual results, will be published in scientific journals and in the media.
5. The research team is committed to treating participants with Respect and Privacy through interviews and measurements conducted in private.

Name: ______________________________ Date : ______________________________

Signature: ___________________________ Thumbprint: [ ] (*if no signature*)

Name and signature of student investigator: ___________________________ ______________________

**Unique participation identification number (PID):** _____-_____-_____

**Figure D.2**: **Participant informed consent form.**

**Project title:**

**Growth curve analysis and new standard development for South African children aged 0 – 3 years of Mixed Ancestry ('Coloured')**

*'Organisation's name'*

*'Address'*

Dear [*person in charge*],

**Who are we, and why are we doing this study?**
I am Liesl Arendse, a PhD student from the University of Cape Town. My supervisors and I are interested in the growth of children from the Mixed Ancestry ('Coloured') community between the ages of 0 – 3 years. A study like this has never been done before, but we know from previous studies that where a person is raised can affect how they grow. This study will help us understand how children's growth is affected by their home environment, the area that they grow up in and different feeding methods. This is important so that we can help them reach their full height potential. We would like to ask your permission to do data collection at your facility.

**Permission**
I require your permission to conduct this research at your facility. Your organisation was chosen as a unique location to study children from the Mixed Ancestry ('Coloured') community due to the diversity of the population within your catchment region, and also their diverse socio-ecological and socio-economic environment. I understand that I cannot conduct any research without your permission. I implore you to consider my request.

**How will your family planning clinic/organisation be involved?**
If your family planning clinic/organisation participate, it would involve some of your visiting mothers/primary caregivers/legal guardians. They will be given a pamphlet describing why we're doing the study and what we require from them. Once they have given consent to participation, they will be asked to answer some questions about their home environment, food security and some medical history. They'll do this while waiting to see the nurse. It should take about 25 – 30 minutes. Would it be possible for me to interview them in a private space in your facility?

When this is done, they will wait until it's their turn for their consultation with the nursing staff to take weight, height and head circumference measurements of their child. Instead of your staff taking the measurements, I will take it for them. When we're done with the child's measurements, we would then like to take the height and weight measurement of the child's birth mother if she is available and has given consent. This should take about 5 – 10 minutes.

I will ask the primary caregiver to hold the child's head while I straighten the child's knees to take their height measurement. It will be less stressful for the child if their primary caregiver does this. For the weight measurement, a new nappy (which we will provide) will be placed on the scale and the child placed on it. No clothes or worn nappy. I will sanitise all measuring equipment between participants.

I know that you as an organisation are pressed for time on a normal day and that you have a very high daily turnover of clientele, and I do not wish to add an additional burden to your workload. I will try not to delay you unnecessarily from your daily routine.

**Figure D.3: Community-based organisation information sheet.**

**Are there any risks to your organisation's participation?**
No. All results and discussions in articles that will be published from the data collected at your organisation, will not mention the name of the family planning clinic or organisation. For publication purposes, the names of the children and primary caregivers/mothers will remain anonymous as data will be analysed collectively.

**How will your organisation benefit from this study?**
There is no direct benefit to your organisation. However, this study will help us to better understand the physical growth of these children under different socio-economic and socio-ecological conditions, and determine the relative contributions of familial and maternal factors, to the growth trajectory in infants and children of the 'Coloured' (Mixed Ancestry) community. This can help us develop programs to improve their development. We will also provide your organisation with feedback at the end of the study.

Any further questions can be directed to me on 084 258 8225 or at arnlie002@myuct.ac.za. If you have questions related to the ethics of this study, please contact: Prof Marc Blockman, Chairperson of the University of Cape Town's Human Research Ethics Committee (HREC), which is an independent committee established to 'oversee the safety, rights and welfare of human participants in research'. Prof Blockman can be reached at (021) 406 6496 (Tel.), (021) 448 1989 (Fax) or marck.blockman@uct.ac.za.

Thank you for your time and attention.

Kind regards

Ms Liesl Arendse
Student Researcher: PhD in Anatomy
University of Cape Town

Supervisors:
Dr. V. Gibbon (UCT) : victoria.gibbon@uct.ac.za
Prof E.V. Lambert (UCT) : vicki.lambert@uct.ac.za
Dr. D. Brits (WITS) : Desire.Brits@wits.ac.za

**Figure D.3 (continues)**: **Community-based organisation information sheet.**

## Appendix E: Questionnaires

**PLEASE COMPLETE FULLY (all areas must be completed):**

**A. Socio-economic status (SES)**

| | | | | | |
|---|---|---|---|---|---|
| Infant's age (months) | | Mother's age (years) | | Father's age (years) | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **1. Population group self-identification** | Coloured | Cape Malay | Khoe | San | Khoesan | Bushmen | Mixed Ancestry | Other (Specify): |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **2.HOME** | Own | | Rent | | Stay with family | | Informal | | Single or multi-family | |

| | | | | | | |
|---|---|---|---|---|---|---|
| **No. of people in residence** | Adults | | Children aged 3-18 | | Children younger than 3 years | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **3.1 EMPLOYMENT** | Permanent | | Contract | | Irregular | | Unemployed | | Grant | |

| | | | | | | |
|---|---|---|---|---|---|---|
| **3.2 SALARY SCALE *** | < R 80 000 pa | | R 80 000 – R 350 000 pa | | > R 350 000 pa | |
| **3.3 EDUCATION** | What is the highest grade/degree completed? | | | | | |
| How would you describe your literacy proficiency? | | | | | | |

***Salary scale is the combined income of primary caregiver(s) (i.e. mother and/or father or guardian).***

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **4.1 NUMBER of DEPENDENTS** | **1** | | **2** | | **3** | | **4** | | **5 or more** | |
| **4.2 Ages:** | | | | | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **5. FOOD CONSUMPTION** | | | | | | | | |
| **Describe the major components of a meal? *E.g.* porridge; pap & meat; salad *etc.*** | | | | | | | | |
| Breakfast | | | | How many days per week? | | Other | | |
| Lunch | | | | How many days per week? | | Other | | |
| Supper | | | | How many days per week? | | Other | | |
| Snack(s) | Mostly sugar | | Mostly fruit | | Both | | Other: specify | | How many days per week? | |
| Additional information | | | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **6.1 Sanitation** | **In-house** | | **Outside** | | **Public** | | **Other (specify)** | |
| **6.2 Water source** | **In-house** | | **Public** | | **Other (specify)** | | | |

**B. Medical history of infant and primary caregiver(s)**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **7. MEDICAL CARE Cost** | **Private Care** | Medical Aid | Cash | Both | **Public** | | **Both** | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **8. MEDICAL HISTORY** | | | | | | | | |
| **8.1 Infant:** | Gestational age (weeks) | | Status at birth | Healthy | Underweight | Other: | | |
| **Feeding** | Exclusively breastfed | | Exclusively formula fed | | Both | | Other: Specify | |
| **Immunisations** | All | Some | None | Reason if not all up to date | | | | |
| **De-worming** | All | Some | None | Reason if not all up to date | | | | |
| **Vitamin booster shots** | | Age (months) | | Reason | | | | |

**Figure E.1: A. Socio-economic status (SES) and B. Medical history for primary caregiver(s) and infant questionnaires.**

| **Illnesses: Diagnosed or suspected** | HIV-infected (positive) | Foetal Alcohol Syndrome | Pulmonary diseases | Coronary diseases | Other: Specify please. |
|---|---|---|---|---|---|

| **Started solids** | Age (months) started | | Type(s) | | Age when more solids than milk/milk supplements | |
|---|---|---|---|---|---|---|

| **History of illnesses:** Illnesses | | Severity of illness: Quick recovery or hospitalisation? | Duration (days) |
|---|---|---|---|
| **(i)** | | | |
| **(ii)** | | | |
| **(iii)** | | | |
| **(iv)** | | | |
| **(v)** | | | |

| **8.2 Birth Mother:** | | Age (years) | | General health status during pregnancy | |
|---|---|---|---|---|---|
| Weight (kg) | | Height (cm) | | Additional Notes | |

| | | | |
|---|---|---|---|
| Where there any health issues during the pregnancy? Specify please. | | | |
| Did the mother gain weight according to the norm? | Yes | No | If no, explain? |

**8.3 Does the birth mother:**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Smoke | | If yes: | During pregnancy | | After pregnancy while breastfeeding | | No. /day | |
| Alcohol intake | | If yes: | During pregnancy | | After pregnancy while breastfeeding | | No Drinks. /day | |
| Use recreational drugs | | If yes: | During pregnancy | | After pregnancy while breastfeeding | | | |

| | | | |
|---|---|---|---|
| If the primary caregiver does not smoke, does anyone else smoke in the infant's environment? | | No. | |
| Other health concerns: *i.e.* TB, diabetes *etc.* | | | |

**8.4 Family medical history:**

| | | | | |
|---|---|---|---|---|
| Are there any chronic diseases in the family? If yes, please specify below. | | | Yes | No |
| Mother's side | | Birth mother: HIV-status known | Yes | No |
| Father's side | | Biological father: HIV-status known | Yes | No |

**Data analyses number:**

| Prov. | Area | No. |
|---|---|---|
| | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Date: | Data collection point: | | | | | |
| Infant clinic/hospital record number | | | | | | |
| Questionnaire completed | **A.** SES: | YES | NO | **B.** Medical History: | YES | NO |
| **Data Captured** | | **Date captured:** | | | | |
| **Additional Notes:** | | | | | | |

**Figure E.1 (continues):** **A. Socio-economic status (SES) and B. Medical history for primary caregiver(s) and infant questionnaires.**

**PARTICIPANT NO.: ____-____-____**

**HOUSEHOLD FOOD INSECURITY ACCESS SCALE (HFIAS)**

*(READ the list and categories and* ***circle only ONE*** *answer for each question)*

| **Household Food Insecurity Access Scale (HFIAS) for last four weeks** | **No** (Answer to question is "No") | **Rarely** (once or twice) | **Sometimes** (3 to 10 times) | **Often** (more than 10 times) |
|---|---|---|---|---|
| a. In the past four weeks, did you worry that your household would not have enough food? | 1 | 2 | 3 | 4 |
| b. In the past four weeks were you or any household member not able to eat the kinds of foods you preferred because of a lack of resources? | 1 | 2 | 3 | 4 |
| c. In the past four weeks did you or any household member have to eat a limited variety of foods due to a lack of resources? | 1 | 2 | 3 | 4 |
| d. In the past four weeks, did you or any household member have to eat some foods that you really did not want to eat because of a lack of resources to obtain other types of food? | 1 | 2 | 3 | 4 |
| e. In the past four weeks, did you or any household member have to eat a smaller meal than you felt you needed because there was not enough food? | 1 | 2 | 3 | 4 |
| f. In the past four weeks, did you or any household member have to eat fewer meals in a day because there was not enough food? | 1 | 2 | 3 | 4 |
| g. In the past four weeks, was there ever no food to eat of any kind in your household because of lack of resources to get food? | 1 | 2 | 3 | 4 |
| h. In the past four weeks, did you or any household member go to sleep at night hungry because there was not enough food? | 1 | 2 | 3 | 4 |
| i. In the past four weeks, did you or any household member go a whole day and night without eating anything because there was not enough food? | 1 | 2 | 3 | 4 |
| j. In the past week, did you or any household member eat a cooked meal less than once a day? | 1 | 2 | 3 | 4 |

**Figure E.2: Household food insecurity assess scale (HFIAS) questionnaire.**

**Appendix F: Graphic representation of z-score distribution for male versus female, irrespective of socio-economic status (SES) group.**

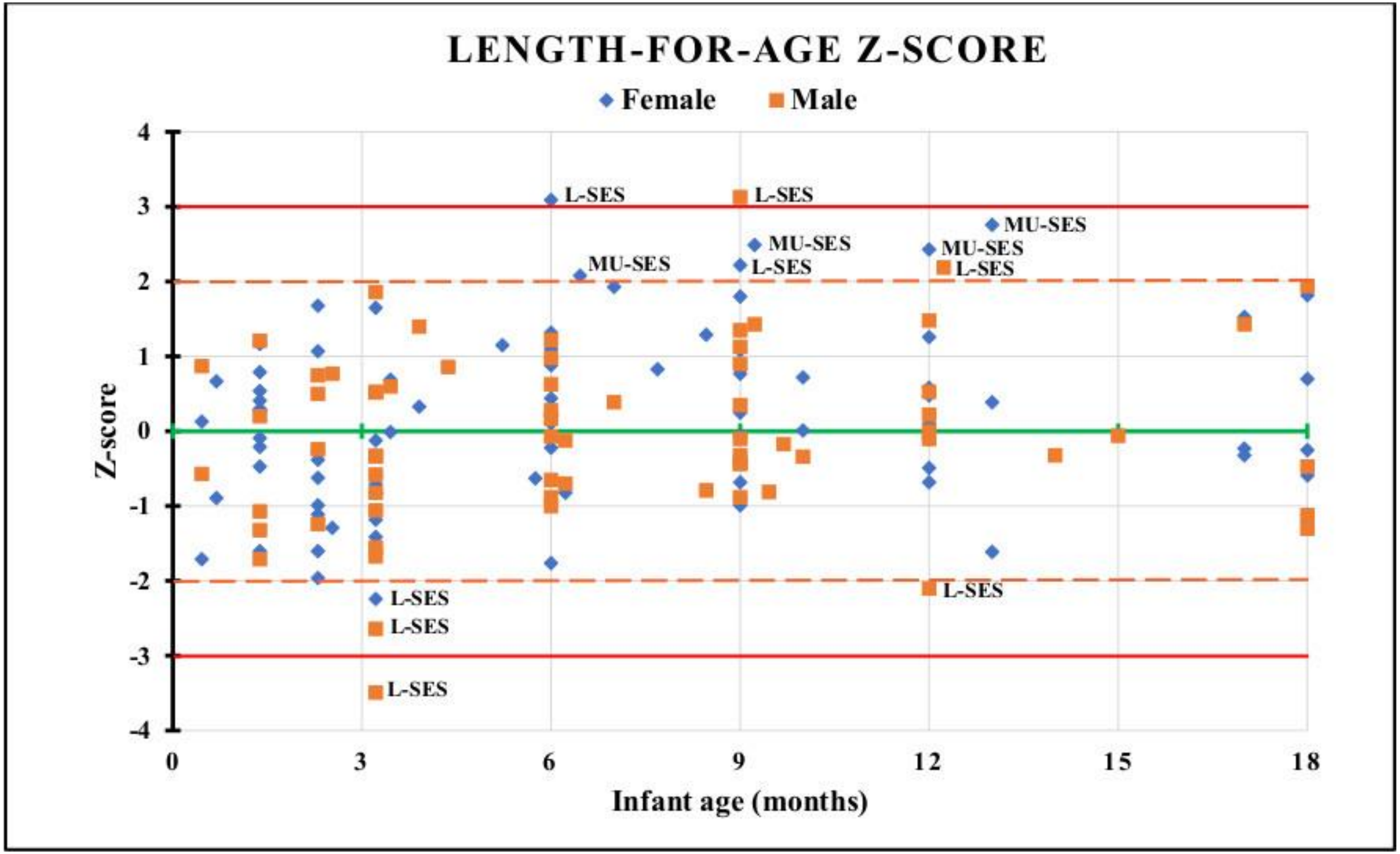


**Figure F.1:** **Length-for-age z-scores of all males and females, irrespective of SES group.**


**Figure F.2:** **Weight-for-age z-scores of all males and females, irrespective of SES group.**

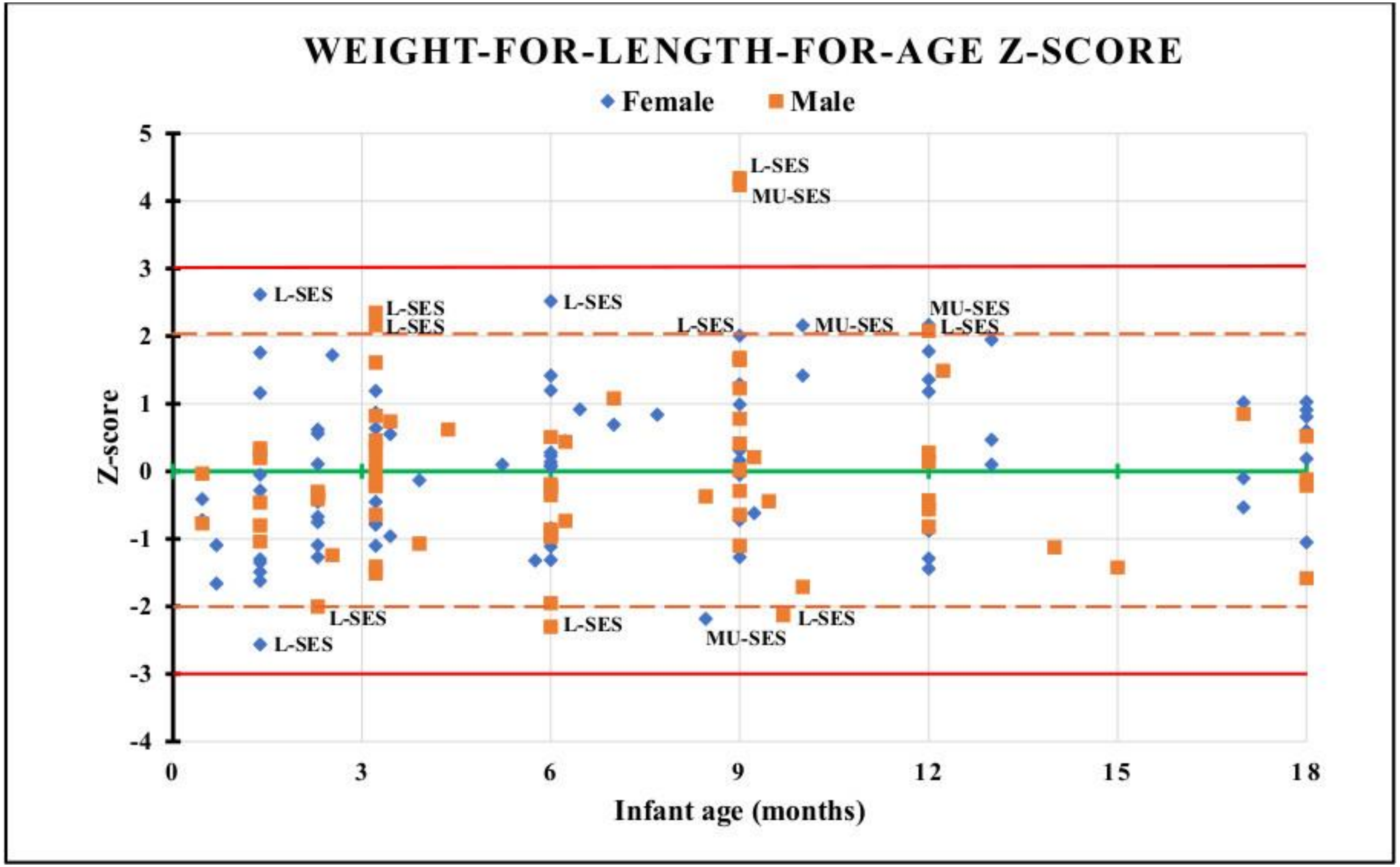


**Figure F.3:** Weight-for-length-for-age z-scores of all males and females, irrespective of SES group.

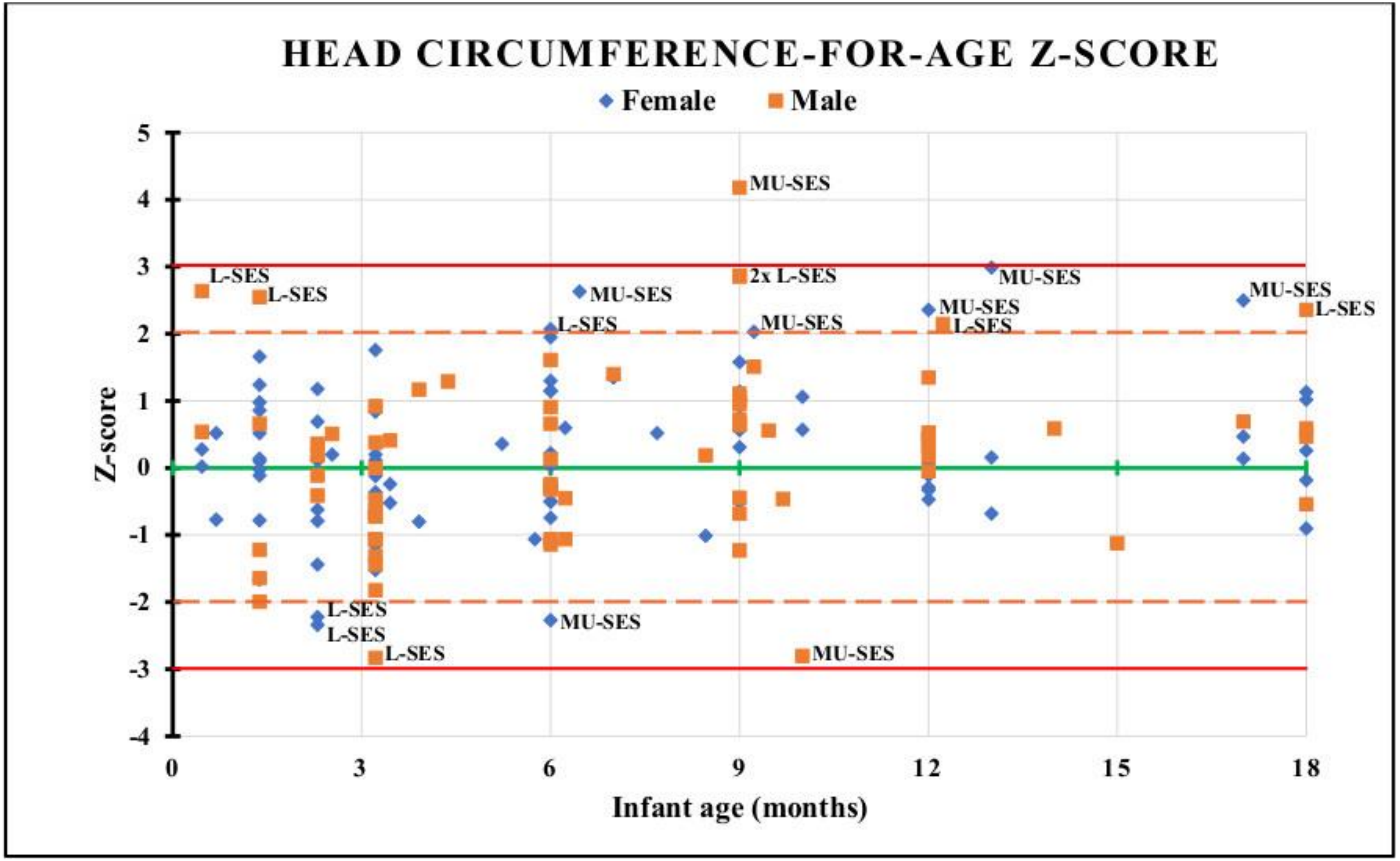


**Figure F.4:** **Head circumference-for-length-for-age z-scores of all males and females, irrespective of SES group.**

**Appendix G: Graphic representation of raw anthropometric measurements data distribution for male versus female, irrespective of socio-economic status (SES) group.**

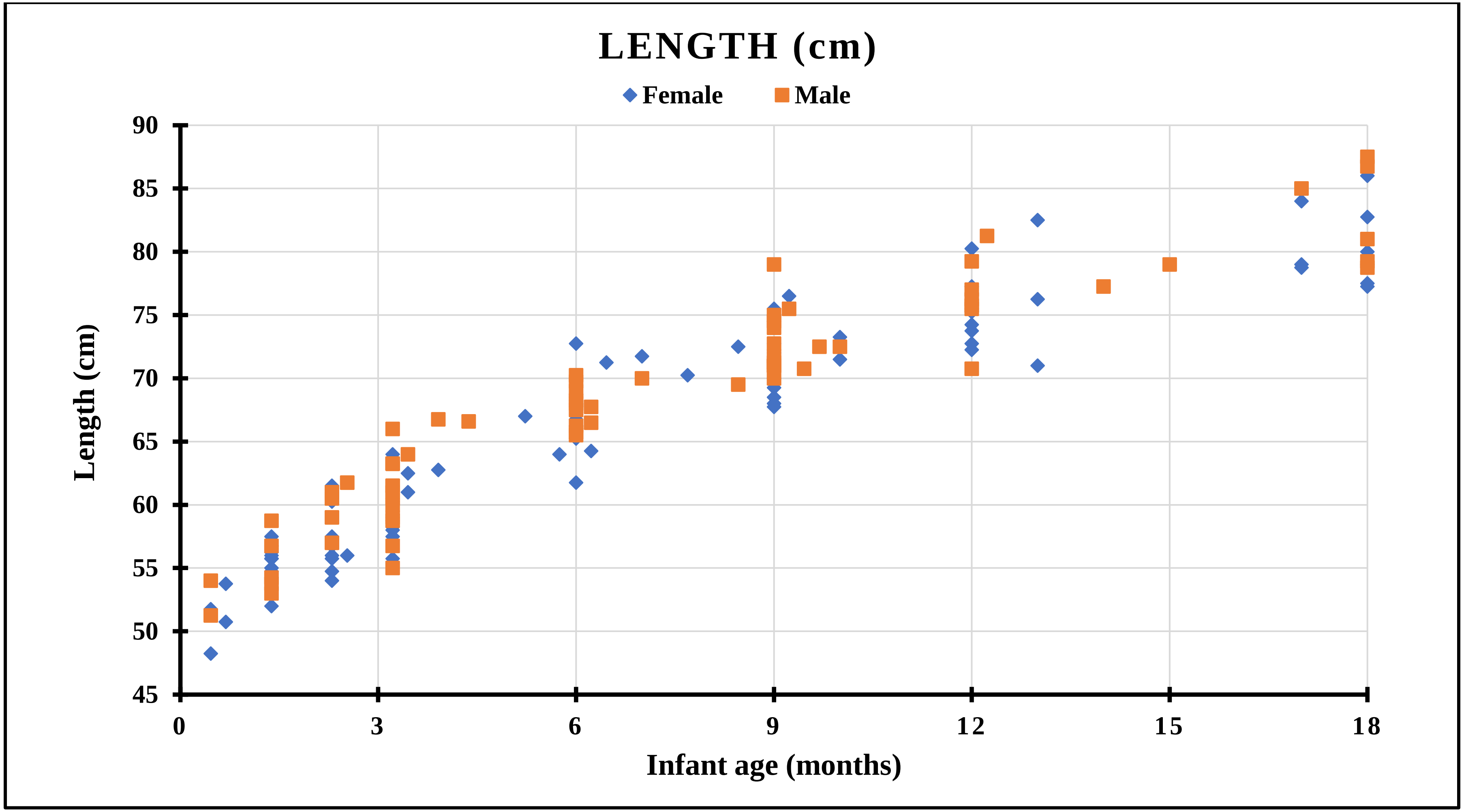


**Figure G.1: Graphic representation of length (cm) distribution for male versus female, irrespective of socio-economic status (SES) group.**

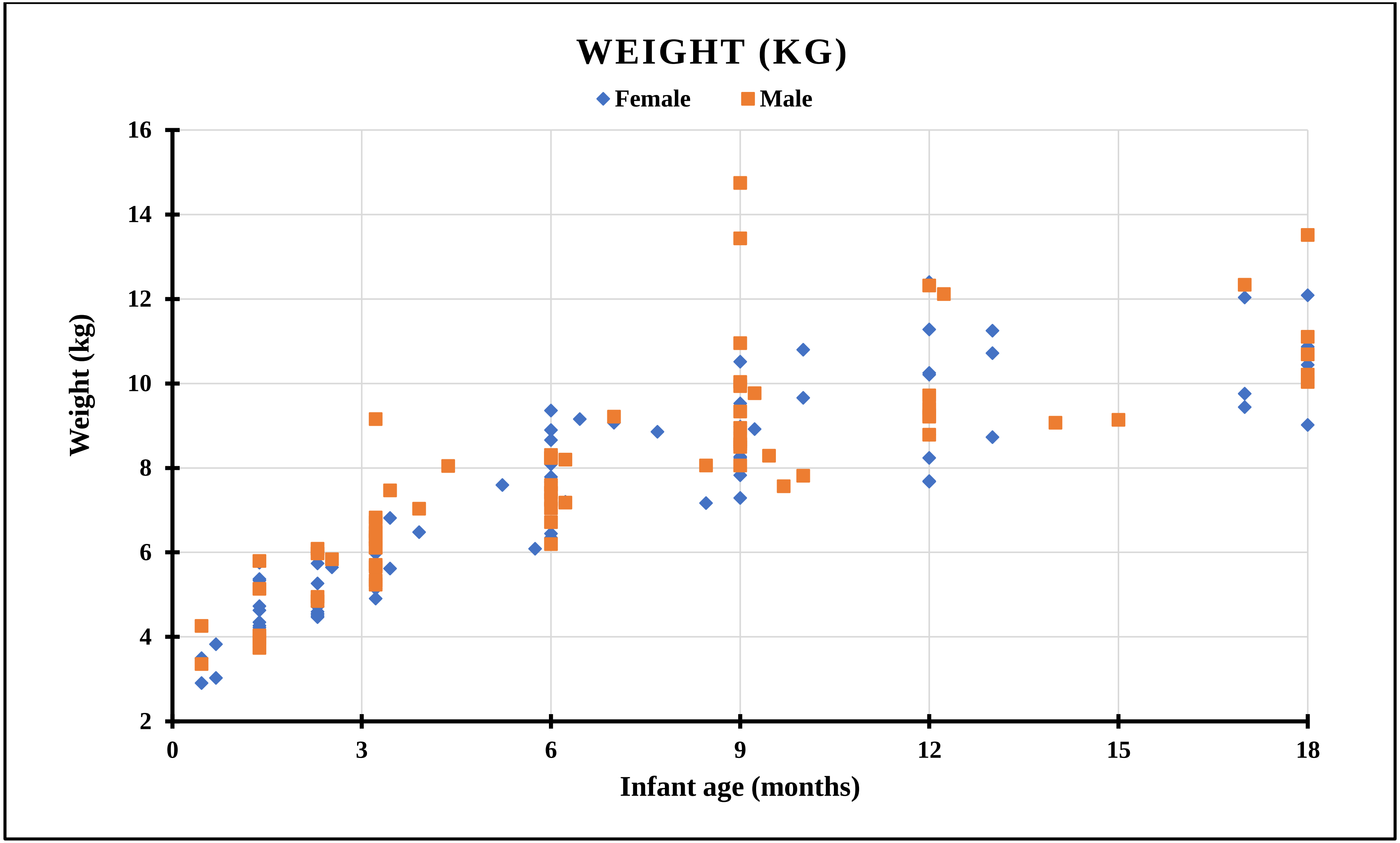


**Figure G.2:** **Graphic representation of weight (kg) distribution for male versus female, irrespective of socio-economic status (SES) group.**

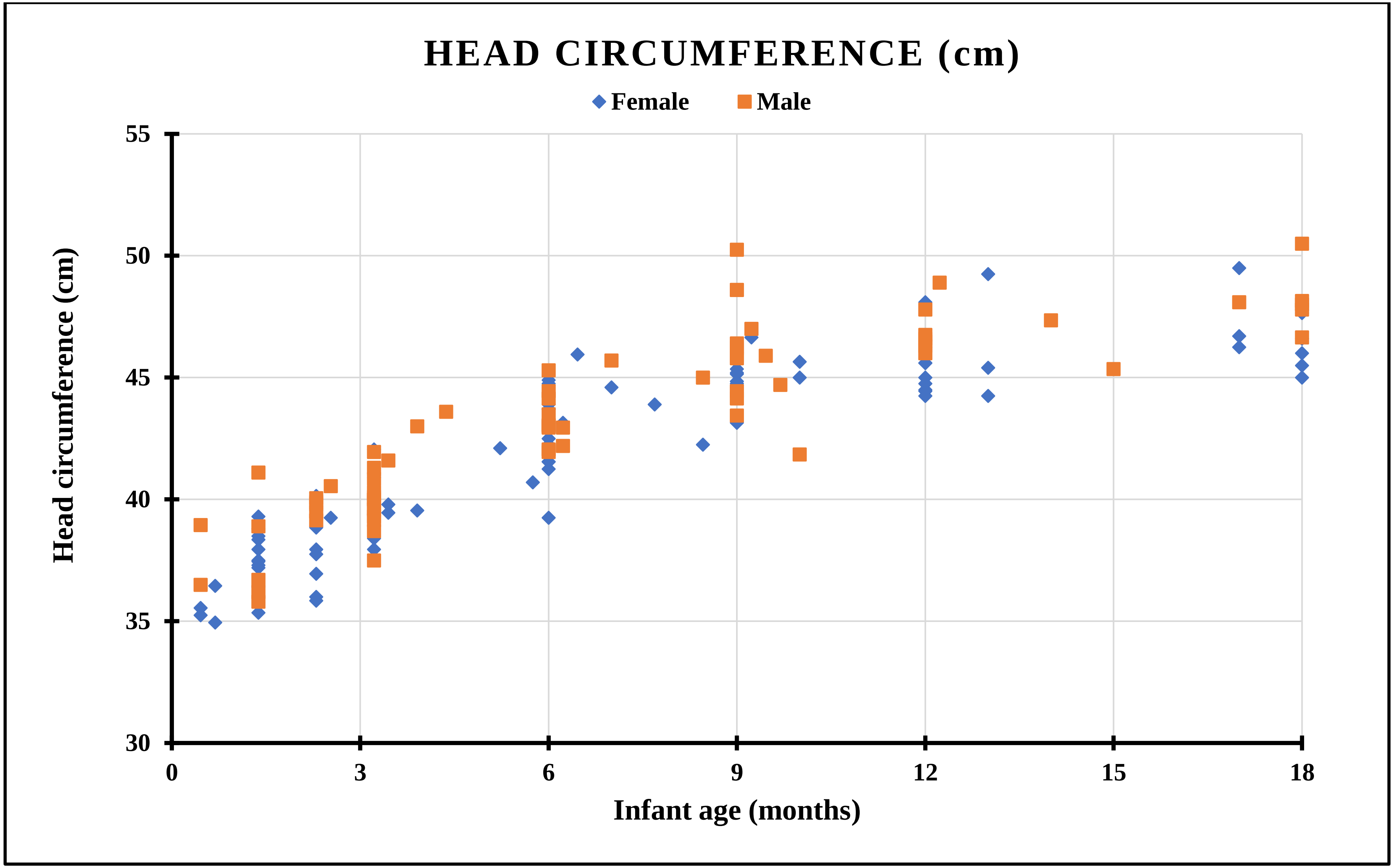


**Figure G.3:** **Graphic representation of head circumference (cm) distribution for male versus female, irrespective of socio-economic status (SES) group.**

**Appendix H: Descriptive statistics for z-scores.**

**Table H.1: Median, mean and standard deviation for z-scores for different categories per age group as indicated.**

| Category | Age group | Category description | | N | Length-for-age | | | Weight-for-age | | | Weight-for-length-for age | | | Head circumference-for-age | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | zlen | | | zwei | | | zwfl | | | zhc | | |
| | | | | | Med | Mean | SD | Med | Mean | SD | Med | Mean | SD | Med | Mean | SD |
| Total age cohort | 0 – 18 months | Male | | 71 | -0.10 | 0.00 | 1.15 | -0.27 | -0.07 | 1.33 | -0.21 | -0.01 | 1.28 | 0.29 | 0.19 | 1.31 |
| | | Female | | 90 | 0.06 | 0.13 | 1.14 | 0.05 | 0.07 | 1.03 | 0.10 | 0.09 | 1.12 | 0.21 | 0.27 | 1.06 |
| | 0 - 5.9 months | Male | | 28 | -0.29 | -0.29 | 1.26 | -0.28 | -0.33 | 1.15 | -0.20 | -0.09 | 1.04 | -0.26 | -0.21 | 1.29 |
| | | Female | | 40 | -0.32 | -0.29 | 0.99 | -0.62 | -0.43 | 0.88 | -0.39 | -0.25 | 1.07 | 0.06 | -0.10 | 0.97 |
| | 6 - 11.9 months | Male | | 28 | -0.11 | 0.14 | 0.94 | -0.30 | 0.08 | 1.57 | -0.27 | 0.05 | 1.59 | 0.38 | 0.40 | 1.44 |
| | | Female | | 30 | 0.58 | 0.60 | 1.13 | 0.47 | 0.50 | 0.91 | 0.30 | 0.35 | 1.12 | 0.65 | 0.64 | 1.02 |
| | 12 – 18 months | Male | | 15 | 0.00 | 0.26 | 1.26 | -0.23 | 0.14 | 1.15 | -0.12 | 0.04 | 1.10 | 0.47 | 0.55 | 0.89 |
| | | Female | | 20 | 0.00 | 0.27 | 1.19 | 0.33 | 0.41 | 1.10 | 0.54 | 0.39 | 1.09 | 0.15 | 0.43 | 1.08 |
| Socio-economic status (SES) group | 0 - 5.9 months | Mid-to-Upper SES | | 20 | 0.31 | 0.28 | 0.80 | -0.14 | -0.23 | 0.85 | -0.66 | -0.56 | 0.67 | -0.01 | 0.04 | 0.71 |
| | | Low SES | | 48 | -0.60 | -0.52 | 1.13 | -0.62 | -0.45 | 1.05 | -0.05 | -0.03 | 1.14 | -0.05 | -0.22 | 1.23 |
| | 6 - 11.9 months | Mid-to-Upper SES | | 17 | -0.22 | 0.23 | 1.14 | 0.01 | 0.37 | 1.45 | 0.23 | 0.41 | 1.60 | 0.57 | 0.50 | 1.74 |
| | | Low SES | | 41 | 0.25 | 0.43 | 1.04 | 0.26 | 0.27 | 1.23 | 0.14 | 0.13 | 1.27 | 0.61 | 0.54 | 1.01 |
| | 12 – 18 months | Mid-to-Upper SES | | 10 | 0.25 | 0.72 | 1.23 | 1.16 | 0.65 | 1.24 | 0.48 | 0.47 | 1.18 | 0.53 | 0.84 | 1.31 |
| | | Low SES | | 25 | -0.06 | 0.09 | 1.17 | -0.14 | 0.15 | 1.05 | 0.19 | 0.15 | 1.06 | 0.29 | 0.34 | 0.82 |
| Sex / SES group | 0 - 5.9 months | Male | Mid-to-Upper SES | 6 | 0.65 | 0.48 | 0.69 | -0.20 | -0.17 | 0.72 | -0.86 | -0.67 | 0.79 | 0.26 | 0.31 | 0.82 |
| | | | Low SES | 22 | -0.58 | -0.50 | 1.31 | -0.44 | -0.38 | 1.25 | -0.03 | 0.06 | 1.05 | -0.57 | -0.35 | 1.37 |
| | | Female | Mid-to-Upper SES | 14 | 0.29 | 0.19 | 0.85 | -0.09 | -0.26 | 0.92 | -0.56 | -0.52 | 0.64 | -0.07 | -0.07 | 0.65 |
| | | | Low SES | 26 | -0.67 | -0.55 | 0.97 | -0.66 | -0.52 | 0.86 | -0.21 | -0.11 | 1.23 | 0.11 | -0.12 | 1.11 |
| | 6 - 11.9 months | Male | Mid-to-Upper SES | 9 | -0.43 | -0.07 | 0.78 | -0.25 | 0.47 | 1.71 | 0.02 | 0.69 | 1.80 | 0.19 | 0.51 | 2.00 |
| | | | Low SES | 19 | -0.07 | 0.22 | 1.01 | -0.35 | -0.07 | 1.53 | -0.35 | -0.21 | 1.47 | 0.56 | 0.35 | 1.22 |
| | | Female | Mid-to-Upper SES | 8 | 0.37 | 0.53 | 1.40 | 0.31 | 0.26 | 1.24 | 0.27 | 0.12 | 1.44 | 0.63 | 0.49 | 1.57 |
| | | | Low SES | 22 | 0.61 | 0.63 | 1.05 | 0.47 | 0.59 | 0.78 | 0.31 | 0.43 | 1.01 | 0.69 | 0.70 | 0.78 |
| | 12 – 18 months | Male | Mid-to-Upper SES | 2 | 0.56 | 0.56 | 1.24 | 0.15 | 0.15 | 1.58 | -0.14 | -0.14 | 1.39 | 0.64 | 0.64 | 0.07 |
| | | | Low SES | 13 | 0.00 | 0.21 | 1.31 | -0.23 | 0.14 | 1.15 | -0.12 | 0.07 | 1.11 | 0.42 | 0.54 | 0.96 |
| | | Female | Mid-to-Upper SES | 8 | 0.25 | 0.76 | 1.31 | 1.16 | 0.78 | 1.23 | 0.56 | 0.62 | 1.18 | 0.31 | 0.89 | 1.48 |
| | | | Low SES | 12 | -0.18 | -0.05 | 1.04 | 0.11 | 0.16 | 0.98 | 0.54 | 0.23 | 1.04 | 0.12 | 0.13 | 0.61 |

N = number of participants Med = median SD = standard deviation

**Appendix I: Original anthropometric measurement data.**

**Table I.1: Original anthropometric measurements of each infant's length, weight, and head circumference including their age, sex, gestational age, exclusive breastfeeding duration, age complementary feeding started, and parental ages.**

**Note:**

**SES group:** 1 = mid-upper socio-economic status (SES) group (MU-SES group) 2 = lower socio-economic status (SES) group (L-SES group)
**Sex**: 1 = male 2 = female

| SES group | Age | Sex | Gestational age (weeks) | Length measurements (cm) | | | | Weight measurement (kg) | | | | Head circumference measurement (cm) | | | | Exclusive breastfed duration (months) | Complementary feeding started (months) | Maternal age (years) | Paternal age (years) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 1 | 2 | 3 | Mean | 1 | 2 | 3 | Mean | 1 | 2 | 3 | Mean | | | | |
| 1 | 0.70 | 1 | 38 | 54.0 | 53.8 | 53.5 | 53.8 | 3.81 | 3.85 | 3.83 | 3.83 | 36.7 | 36.5 | 36.2 | 36.5 | 1.0 | 0.0 | 37 | 44 |
| 1 | 1.40 | 1 | 41 | 57.5 | 57.5 | 57.5 | 57.5 | 5.34 | 5.33 | 5.34 | 5.34 | 36.9 | 36.4 | 35.9 | 36.4 | 1.5 | 0.0 | 36 | 35 |
| 1 | 1.40 | 1 | 38 | 56.0 | 55.8 | 55.5 | 55.8 | 4.63 | 4.63 | 4.63 | 4.63 | 38.9 | 38.8 | 38.7 | 38.8 | 0.5 | 0.0 | 34 | 35 |
| 1 | 1.40 | 1 | 39 | 56.0 | 55.8 | 55.5 | 55.8 | 4.16 | 4.16 | 4.16 | 4.16 | 37.2 | 37.3 | 37.4 | 37.3 | 1.5 | 0.0 | 31 | 35 |
| 1 | 2.33 | 1 | 39 | 57.5 | 57.5 | 57.5 | 57.5 | 5.17 | 5.37 | 5.27 | 5.27 | 38.7 | 38.9 | 39.0 | 38.9 | 2.0 | 0.0 | 27 | 31 |
| 1 | 2.33 | 1 | 40 | 61.5 | 61.5 | 61.5 | 61.5 | 5.95 | 6.05 | 6.00 | 6.00 | 39.5 | 39.6 | 39.6 | 39.6 | 0.0 | 0.0 | 34 | 34 |
| 1 | 2.33 | 1 | 37 | 56.0 | 55.8 | 55.5 | 55.8 | 4.48 | 4.46 | 4.47 | 4.47 | 37.9 | 38.0 | 38.0 | 38.0 | 1.0 | 0.0 | 22 | 25 |
| 1 | 3.27 | 1 | 39 | 58.5 | 58.3 | 58.0 | 58.3 | 4.89 | 4.93 | 4.91 | 4.91 | 40.2 | 40.1 | 40.0 | 40.1 | 3.0 | 0.0 | 28 | 28 |
| 1 | 3.27 | 1 | 40 | 59.5 | 59.3 | 59.0 | 59.3 | 5.27 | 5.31 | 5.29 | 5.29 | 39.6 | 39.7 | 39.8 | 39.7 | 2.0 | 0.0 | 21 | 23 |
| 1 | 3.50 | 1 | 40 | 61.0 | 61.0 | 61.0 | 61.0 | 5.65 | 5.58 | 5.62 | 5.62 | 39.8 | 39.8 | 39.8 | 39.8 | 2.0 | 0.0 | 27 | 30 |
| 1 | 3.50 | 1 | 37 | 62.5 | 62.5 | 62.5 | 62.5 | 6.80 | 6.85 | 6.83 | 6.83 | 39.5 | 39.5 | 39.4 | 39.5 | 3.0 | 0.0 | 19 | 28 |
| 1 | 3.97 | 1 | 40 | 63.0 | 62.8 | 62.5 | 62.8 | 6.49 | 6.46 | 6.48 | 6.48 | 39.6 | 39.6 | 39.5 | 39.6 | 4.0 | 0.0 | 35 | 29 |
| 1 | 5.23 | 1 | 40 | 67.0 | 67.0 | 67.0 | 67.0 | 7.56 | 7.63 | 7.60 | 7.60 | 42.0 | 42.1 | 42.2 | 42.1 | 5.0 | 4.0 | 22 | 25 |
| 1 | 5.83 | 1 | 38 | 64.0 | 64.0 | 64.0 | 64.0 | 6.06 | 6.12 | 6.09 | 6.09 | 40.6 | 40.7 | 40.8 | 40.7 | 0.5 | 0.0 | 30 | 32 |
| 1 | 2.57 | 2 | 40 | 61.5 | 61.8 | 62.0 | 61.8 | 5.85 | 5.83 | 5.84 | 5.84 | 40.5 | 40.6 | 40.6 | 40.6 | 1.0 | 0.0 | 21 | 25 |
| 1 | 3.27 | 2 | 39 | 61.5 | 61.5 | 61.5 | 61.5 | 5.71 | 5.61 | 5.66 | 5.66 | 40.3 | 40.3 | 40.3 | 40.3 | 3.0 | 0.0 | 24 | 26 |
| 1 | 3.27 | 2 | 38 | 61.5 | 61.5 | 61.5 | 61.5 | 6.29 | 6.30 | 6.30 | 6.30 | 40.0 | 40.1 | 40.2 | 40.1 | 3.0 | 0.0 | 19 | 24 |
| 1 | 3.27 | 2 | 38 | 63.0 | 63.3 | 63.5 | 63.3 | 6.46 | 6.52 | 6.49 | 6.49 | 40.9 | 40.9 | 40.8 | 40.9 | 3.0 | 0.0 | 34 | 44 |
| 1 | 3.97 | 2 | 39 | 67.0 | 66.8 | 66.5 | 66.8 | 7.03 | 7.05 | 7.04 | 7.04 | 43.0 | 43.0 | 43.0 | 43.0 | 2.0 | 0.0 | 28 | 29 |

| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 4.43 | 2 | 39 | 66.5 | 66.6 | 66.7 | 66.6 | 8.10 | 8.00 | 8.05 | 8.05 | 43.5 | 43.6 | 43.7 | 43.6 | 0.0 | 0.0 | 32 | 32 |
| 2 | 0.47 | 1 | 39 | 48.0 | 48.3 | 48.5 | 48.3 | 2.91 | 2.91 | 2.91 | 2.91 | 35.2 | 35.3 | 35.3 | 35.3 | 0.5 | 0.0 | 31 | 28 |
| 2 | 0.47 | 1 | 40 | 51.5 | 51.8 | 52.0 | 51.8 | 3.50 | 3.50 | 3.50 | 3.50 | 35.5 | 35.6 | 35.6 | 35.6 | 0.5 | 0.0 | 37 | 37 |
| 2 | 0.70 | 1 | 40 | 51.0 | 50.8 | 50.5 | 50.8 | 3.00 | 3.05 | 3.03 | 3.03 | 35.1 | 35.0 | 34.8 | 35.0 | 0.8 | 0.0 | 25 | 35 |
| 2 | 1.40 | 1 | 40 | 54.5 | 55.0 | 54.8 | 54.8 | 5.77 | 5.74 | 5.76 | 5.76 | 39.5 | 39.1 | 39.3 | 39.3 | 1.5 | 0.0 | 31 | 35 |
| 2 | 1.40 | 1 | 40 | 56.5 | 57.0 | 56.8 | 56.8 | 4.00 | 4.01 | 4.01 | 4.01 | 35.5 | 35.2 | 35.4 | 35.4 | 1.5 | 0.0 | 30 | 31 |
| 2 | 1.40 | 1 | 39 | 54.0 | 54.5 | 54.3 | 54.3 | 3.78 | 3.76 | 3.77 | 3.77 | 37.2 | 37.2 | 37.2 | 37.2 | 1.5 | 0.0 | 22 | 25 |
| 2 | 1.40 | 1 | 40 | 56.0 | 56.0 | 56.0 | 56.0 | 4.27 | 4.27 | 4.27 | 4.27 | 37.5 | 37.5 | 37.4 | 37.5 | 1.5 | 0.0 | 17 | 23 |
| 2 | 1.40 | 1 | 40 | 56.0 | 56.3 | 56.5 | 56.3 | 4.35 | 4.35 | 4.35 | 4.35 | 38.2 | 38.4 | 38.5 | 38.4 | 1.5 | 0.0 | 21 | 26 |
| 2 | 1.40 | 1 | 40 | 55.0 | 55.0 | 55.0 | 55.0 | 5.37 | 5.37 | 5.37 | 5.37 | 38.0 | 38.0 | 37.9 | 38.0 | 1.5 | 0.0 | 23 | 21 |
| 2 | 1.40 | 1 | 41 | 55.5 | 55.8 | 56.0 | 55.8 | 4.73 | 4.72 | 4.73 | 4.73 | 37.4 | 37.5 | 37.6 | 37.5 | 0.1 | 0.0 | 42 | 42 |
| 2 | 1.40 | 1 | 40 | 52.0 | 52.0 | 52.0 | 52.0 | 4.16 | 4.27 | 4.22 | 4.22 | 38.5 | 38.5 | 38.5 | 38.5 | 1.5 | 0.0 | 29 | 33 |
| 2 | 2.33 | 1 | 40 | 54.0 | 54.0 | 54.0 | 54.0 | 4.53 | 4.54 | 4.54 | 4.54 | 36.0 | 36.0 | 36.0 | 36.0 | 0.0 | 0.0 | 27 | 29 |
| 2 | 2.33 | 1 | 37 | 56.5 | 56.8 | 57.0 | 56.8 | 4.55 | 4.55 | 4.55 | 4.55 | 37.0 | 37.0 | 36.9 | 37.0 | 2.0 | 0.0 | 16 | 19 |
| 2 | 2.33 | 1 | 37 | 56.0 | 56.0 | 56.0 | 56.0 | 4.50 | 4.49 | 4.50 | 4.50 | 36.0 | 35.9 | 35.7 | 35.9 | 2.0 | 0.0 | 22 | 20 |
| 2 | 2.33 | 1 | 40 | 60.5 | 60.3 | 60.0 | 60.3 | 5.73 | 5.75 | 5.74 | 5.74 | 40.1 | 40.2 | 40.2 | 40.2 | 2.0 | 0.0 | 34 | 35 |
| 2 | 2.33 | 1 | 37 | 54.5 | 54.8 | 55.0 | 54.8 | 4.70 | 4.73 | 4.72 | 4.72 | 37.8 | 37.8 | 37.7 | 37.8 | 0.5 | 0.0 | 33 | 35 |
| 2 | 2.33 | 1 | 40 | 57.0 | 57.3 | 57.5 | 57.3 | 4.60 | 4.59 | 4.60 | 4.60 | 38.8 | 38.9 | 39.0 | 38.9 | 2.0 | 0.0 | 28 | 34 |
| 2 | 2.57 | 1 | 38 | 56.0 | 56.0 | 56.0 | 56.0 | 5.64 | 5.67 | 5.66 | 5.66 | 39.3 | 39.3 | 39.2 | 39.3 | 1.5 | 0.0 | 24 | 32 |
| 2 | 3.27 | 1 | 39 | 59.0 | 59.0 | 59.0 | 59.0 | 5.60 | 5.58 | 5.59 | 5.59 | 39.4 | 39.3 | 39.2 | 39.3 | 3.0 | 0.0 | 30 | 33 |
| 2 | 3.27 | 1 | 39 | 60.0 | 60.3 | 60.5 | 60.3 | 6.30 | 6.29 | 6.30 | 6.30 | 42.1 | 42.1 | 42.0 | 42.1 | 3.0 | 0.0 | 24 | 26 |
| 2 | 3.27 | 1 | 39 | 57.0 | 57.5 | 58.0 | 57.5 | 5.35 | 5.42 | 5.39 | 5.39 | 37.9 | 38.0 | 38.0 | 38.0 | 3.0 | 0.0 | 25 | 34 |
| 2 | 3.27 | 1 | 41 | 58.0 | 58.0 | 58.0 | 58.0 | 5.99 | 5.96 | 5.98 | 5.98 | 39.4 | 39.4 | 39.4 | 39.4 | 2.0 | 0.0 | 35 | 35 |
| 2 | 3.27 | 1 | 40 | 55.5 | 55.8 | 56.0 | 55.8 | 5.15 | 5.15 | 5.15 | 5.15 | 38.5 | 38.4 | 38.3 | 38.4 | 3.0 | 0.0 | 29 | 36 |
| 2 | 3.27 | 1 | 41 | 64.0 | 64.0 | 64.0 | 64.0 | 6.38 | 6.39 | 6.39 | 6.39 | 41.0 | 41.0 | 41.0 | 41.0 | 2.0 | 0.0 | 24 | 27 |
| 2 | 3.27 | 1 | 40 | 58.5 | 58.8 | 59.0 | 58.8 | 5.32 | 5.33 | 5.33 | 5.33 | 40.0 | 40.0 | 40.0 | 40.0 | 3.0 | 0.0 | 31 | 34 |
| 2 | 3.27 | 1 | 38 | 58.6 | 58.8 | 59.0 | 58.8 | 5.55 | 5.54 | 5.55 | 5.55 | 40.8 | 40.9 | 41.0 | 40.9 | 3.0 | 0.0 | 26 | 24 |
| 2 | 0.47 | 2 | 40 | 54.0 | 54.0 | 54.0 | 54.0 | 4.25 | 4.26 | 4.26 | 4.26 | 38.9 | 39.0 | 39.0 | 39.0 | 0.5 | 0.0 | 39 | 32 |
| 2 | 0.47 | 2 | 38 | 51.0 | 51.3 | 51.5 | 51.3 | 3.36 | 3.36 | 3.36 | 3.36 | 36.4 | 36.5 | 36.6 | 36.5 | 0.5 | 0.0 | 38 | 37 |
| 2 | 1.40 | 2 | 40 | 56.5 | 56.8 | 57.0 | 56.8 | 5.13 | 5.14 | 5.14 | 5.14 | 38.8 | 38.9 | 39.0 | 38.9 | 1.5 | 0.0 | 24 | 28 |
| 2 | 1.40 | 2 | 40 | 54.0 | 53.8 | 53.5 | 53.8 | 4.03 | 4.04 | 4.04 | 4.04 | 36.4 | 36.2 | 36.0 | 36.2 | 1.5 | 0.0 | 26 | 31 |
| 2 | 1.40 | 2 | 39 | 54.0 | 54.3 | 54.5 | 54.3 | 3.97 | 3.97 | 3.97 | 3.97 | 36.0 | 35.8 | 35.6 | 35.8 | 1.5 | 0.0 | 35 | 36 |

| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 1.40 | 2 | 40 | 58.5 | 58.8 | 59.0 | 58.8 | 5.80 | 5.80 | 5.80 | 5.80 | 41.2 | 41.1 | 41.0 | 41.1 | 1.5 | 0.0 | 30 | 31 |
| 2 | 1.40 | 2 | 37 | 53.0 | 53.0 | 53.0 | 53.0 | 3.74 | 3.73 | 3.74 | 3.74 | 36.7 | 36.7 | 36.7 | 36.7 | 0.0 | 0.0 | 27 | - |
| 2 | 2.33 | 2 | 39 | 60.5 | 60.5 | 60.5 | 60.5 | 5.99 | 5.97 | 5.98 | 5.98 | 39.4 | 39.6 | 39.5 | 39.5 | 2.0 | 0.0 | 39 | 45 |
| 2 | 2.33 | 2 | 38 | 59.0 | 59.0 | 59.0 | 59.0 | 4.84 | 4.86 | 4.85 | 4.85 | 39.1 | 39.2 | 39.2 | 39.2 | 0.5 | 0.0 | 27 | 42 |
| 2 | 2.33 | 2 | 40 | 61.0 | 61.0 | 61.0 | 61.0 | 6.09 | 6.08 | 6.09 | 6.09 | 39.8 | 39.9 | 39.9 | 39.9 | 2.0 | 0.0 | 35 | 31 |
| 2 | 2.33 | 2 | 38 | 57.0 | 57.0 | 57.0 | 57.0 | 4.96 | 4.94 | 4.95 | 4.95 | 40.1 | 40.1 | 40.0 | 40.1 | 2.0 | 0.0 | 26 | 30 |
| 2 | 3.27 | 2 | 37 | 63.0 | 63.5 | 63.3 | 63.3 | 6.82 | 6.84 | 6.83 | 6.83 | 39.2 | 39.4 | 39.3 | 39.3 | 1.0 | 0.0 | 31 | 24 |
| 2 | 3.27 | 2 | 37 | 57.0 | 56.8 | 56.5 | 56.8 | 6.09 | 6.12 | 6.11 | 6.11 | 39.2 | 39.2 | 39.1 | 39.2 | 3.0 | 0.0 | 25 | 26 |
| 2 | 3.27 | 2 | 37 | 60.0 | 60.0 | 60.0 | 60.0 | 5.34 | 5.33 | 5.34 | 5.34 | 38.6 | 38.7 | 38.8 | 38.7 | 0.0 | 0.8 | 23 | 21 |
| 2 | 3.27 | 2 | 40 | 60.5 | 60.5 | 60.5 | 60.5 | 6.36 | 6.38 | 6.37 | 6.37 | 40.0 | 40.0 | 40.0 | 40.0 | 2.0 | 0.0 | 19 | 25 |
| 2 | 3.27 | 2 | 40 | 59.0 | 59.0 | 59.0 | 59.0 | 6.13 | 6.10 | 6.12 | 6.12 | 37.5 | 37.5 | 37.5 | 37.5 | 2.0 | 0.0 | 26 | 28 |
| 2 | 3.27 | 2 | 37 | 58.5 | 58.8 | 59.0 | 58.8 | 5.72 | 5.69 | 5.71 | 5.71 | 39.5 | 39.6 | 39.7 | 39.6 | 1.0 | 0.0 | 42 | - |
| 2 | 3.27 | 2 | 37 | 63.5 | 63.3 | 63.0 | 63.3 | 6.71 | 6.73 | 6.72 | 6.72 | 41.4 | 41.3 | 41.2 | 41.3 | 2.0 | 0.0 | 25 | 29 |
| 2 | 3.27 | 2 | 39 | 66.0 | 66.0 | 66.0 | 66.0 | 9.17 | 9.15 | 9.16 | 9.16 | 41.9 | 42.0 | 42.0 | 42.0 | 3.0 | 0.0 | 33 | 29 |
| 2 | 3.27 | 2 | 37 | 61.0 | 61.0 | 61.0 | 61.0 | 6.45 | 6.44 | 6.45 | 6.45 | 39.8 | 39.6 | 39.4 | 39.6 | 0.3 | 0.0 | 28 | 31 |
| 2 | 3.27 | 2 | 39 | 55.0 | 55.0 | 55.0 | 55.0 | 5.25 | 5.23 | 5.24 | 5.24 | 40.0 | 40.0 | 40.0 | 40.0 | 2.0 | 0.0 | 25 | 23 |
| 2 | 3.50 | 2 | 41 | 64.0 | 64.0 | 64.0 | 64.0 | 7.43 | 7.51 | 7.47 | 7.47 | 41.5 | 41.6 | 41.7 | 41.6 | 0.8 | 0.0 | 28 | 34 |
| 1 | 6.00 | 1 | 39 | 65.5 | 65.3 | 65.0 | 65.3 | 6.31 | 6.38 | 6.35 | 6.35 | 39.2 | 39.3 | 39.3 | 39.3 | 0.0 | 6.0 | 34 | 35 |
| 1 | 6.00 | 1 | 39 | 61.0 | 61.8 | 62.5 | 61.8 | 6.45 | 6.44 | 6.45 | 6.45 | 42.5 | 42.5 | 42.5 | 42.5 | 2.0 | 5.5 | 30 | 34 |
| 1 | 6.47 | 1 | 38 | 71.0 | 71.3 | 71.5 | 71.3 | 9.20 | 9.11 | 9.16 | 9.16 | 46.0 | 46.0 | 45.9 | 46.0 | 2.0 | 4.0 | 20 | 23 |
| 1 | 8.47 | 1 | 40 | 72.5 | 72.5 | 72.5 | 72.5 | 7.13 | 7.21 | 7.17 | 7.17 | 42.2 | 42.3 | 42.3 | 42.3 | 6.0 | 6.0 | 31 | 31 |
| 1 | 9.00 | 1 | 38 | 69.0 | 69.3 | 69.5 | 69.3 | 8.30 | 8.17 | 8.24 | 8.24 | 44.7 | 44.8 | 44.8 | 44.8 | 0.0 | 6.0 | 34 | 33 |
| 1 | 9.23 | 1 | 38 | 76.5 | 76.5 | 76.5 | 76.5 | 8.98 | 8.85 | 8.92 | 8.92 | 46.5 | 46.7 | 46.8 | 46.7 | 5.5 | 5.5 | 26 | 26 |
| 1 | 10.00 | 1 | 40 | 71.5 | 71.5 | 71.5 | 71.5 | 9.64 | 9.68 | 9.66 | 9.66 | 45.6 | 45.7 | 45.7 | 45.7 | 3.0 | 6.0 | 35 | 36 |
| 1 | 10.00 | 1 | 40 | 73.0 | 73.3 | 73.5 | 73.3 | 10.82 | 10.78 | 10.80 | 10.80 | 45.0 | 45.0 | 45.0 | 45.0 | 3.0 | 6.0 | 30 | 39 |
| 1 | 6.00 | 2 | 39 | 65.5 | 65.5 | 65.5 | 65.5 | 7.22 | 7.26 | 7.24 | 7.24 | 43.2 | 43.0 | 42.8 | 43.0 | 5.0 | 5.0 | 27 | 28 |
| 1 | 7.00 | 2 | 41 | 70.0 | 70.0 | 70.0 | 70.0 | 9.23 | 9.21 | 9.22 | 9.22 | 45.7 | 45.7 | 45.7 | 45.7 | 6.0 | 6.0 | 30 | 31 |
| 1 | 8.47 | 2 | 38 | 69.5 | 69.5 | 69.5 | 69.5 | 7.98 | 8.14 | 8.06 | 8.06 | 45.0 | 45.0 | 45.0 | 45.0 | 4.0 | 4.0 | 25 | 30 |
| 1 | 9.00 | 2 | 38 | 71.0 | 71.0 | 71.0 | 71.0 | 9.92 | 9.96 | 9.94 | 9.94 | 46.0 | 46.2 | 46.4 | 46.2 | 6.0 | 6.0 | 42 | 38 |
| 1 | 9.00 | 2 | 39 | 71.0 | 71.0 | 71.0 | 71.0 | 8.67 | 8.65 | 8.66 | 8.66 | 44.0 | 44.2 | 44.3 | 44.2 | 1.0 | 6.0 | 25 | 23 |
| 1 | 9.00 | 2 | 38 | 74.5 | 74.5 | 74.5 | 74.5 | 10.00 | 10.07 | 10.04 | 10.04 | 46.5 | 46.4 | 46.3 | 46.4 | 1.0 | 9.0 | 41 | 39 |
| 1 | 9.00 | 2 | 40 | 74.0 | 74.0 | 74.0 | 74.0 | 13.44 | 13.44 | 13.44 | 13.44 | 50.1 | 50.3 | 50.4 | 50.3 | 3.0 | 4.0 | 33 | 40 |

| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 10.00 | 2 | 37 | 72.0 | 72.5 | 73.0 | 72.5 | 7.66 | 7.98 | 7.82 | 7.82 | 42.2 | 41.9 | 41.5 | 41.9 | 0.5 | 7.0 | 23 | 22 |
| 2 | 6.00 | 1 | 41 | 66.0 | 66.0 | 66.0 | 66.0 | 7.36 | 7.38 | 7.37 | 7.37 | 41.3 | 41.3 | 41.2 | 41.3 | 1.0 | 5.5 | 17 | 18 |
| 2 | 6.00 | 1 | 40 | 72.5 | 72.8 | 73.0 | 72.8 | 8.08 | 8.09 | 8.09 | 8.09 | 44.5 | 44.8 | 45.0 | 44.8 | 6.0 | 0.0 | 40 | 39 |
| 2 | 6.00 | 1 | 37 | 66.0 | 66.3 | 66.5 | 66.3 | 7.43 | 7.39 | 7.41 | 7.41 | 41.7 | 41.6 | 41.4 | 41.6 | 5.0 | 6.0 | 31 | 35 |
| 2 | 6.00 | 1 | 40 | 68.5 | 68.3 | 68.0 | 68.3 | 8.90 | 8.89 | 8.90 | 8.90 | 43.9 | 43.9 | 43.9 | 43.9 | 2.0 | 4.0 | 25 | 36 |
| 2 | 6.00 | 1 | 42 | 68.0 | 68.0 | 68.0 | 68.0 | 8.65 | 8.66 | 8.66 | 8.66 | 45.0 | 44.9 | 44.8 | 44.9 | 3.0 | 0.0 | 26 | 26 |
| 2 | 6.00 | 1 | 40 | 68.5 | 68.8 | 69.0 | 68.8 | 7.14 | 7.17 | 7.16 | 7.16 | 42.2 | 42.3 | 42.3 | 42.3 | 0.3 | 5.0 | 23 | 28 |
| 2 | 6.00 | 1 | 40 | 68.0 | 67.8 | 67.5 | 67.8 | 7.80 | 7.78 | 7.79 | 7.79 | 43.8 | 43.7 | 43.6 | 43.7 | 5.0 | 4.0 | 28 | 32 |
| 2 | 6.00 | 1 | 40 | 66.5 | 66.8 | 67.0 | 66.8 | 7.66 | 7.68 | 7.67 | 7.67 | 41.6 | 41.6 | 41.5 | 41.6 | 0.0 | 0.0 | 25 | 22 |
| 2 | 6.00 | 1 | 38 | 66.0 | 66.3 | 66.5 | 66.3 | 9.34 | 9.37 | 9.36 | 9.36 | 43.6 | 43.7 | 43.8 | 43.7 | 3.0 | 0.0 | 37 | 37 |
| 2 | 6.23 | 1 | 40 | 64.0 | 64.3 | 64.5 | 64.3 | 7.21 | 7.19 | 7.20 | 7.20 | 43.2 | 43.2 | 43.1 | 43.2 | 0.5 | 6.0 | 39 | 37 |
| 2 | 7.00 | 1 | 38 | 71.5 | 71.8 | 72.0 | 71.8 | 9.06 | 9.07 | 9.07 | 9.07 | 44.5 | 44.6 | 44.7 | 44.6 | 2.0 | 4.0 | 22 | 25 |
| 2 | 7.70 | 1 | 39 | 70.0 | 70.3 | 70.5 | 70.3 | 8.87 | 8.86 | 8.87 | 8.87 | 44.0 | 43.9 | 43.8 | 43.9 | 4.0 | 4.0 | 35 | 36 |
| 2 | 9.00 | 1 | 42 | 74.5 | 74.5 | 74.5 | 74.5 | 8.63 | 8.35 | 8.49 | 8.49 | 44.7 | 44.7 | 44.6 | 44.7 | 4.0 | 4.0 | 35 | 34 |
| 2 | 9.00 | 1 | 40 | 70.0 | 70.0 | 70.0 | 70.0 | 7.28 | 7.30 | 7.29 | 7.29 | 44.8 | 44.9 | 44.9 | 44.9 | 6.0 | 6.0 | 35 | 41 |
| 2 | 9.00 | 1 | 42 | 75.5 | 75.5 | 75.5 | 75.5 | 9.56 | 9.49 | 9.53 | 9.53 | 44.4 | 44.6 | 44.8 | 44.6 | 6.0 | 6.0 | 24 | 31 |
| 2 | 9.00 | 1 | 42 | 68.5 | 68.5 | 68.5 | 68.5 | 8.86 | 8.84 | 8.85 | 8.85 | 43.1 | 43.2 | 43.2 | 43.2 | 2.0 | 4.0 | 28 | 62 |
| 2 | 9.00 | 1 | 42 | 72.0 | 72.0 | 72.0 | 72.0 | 8.55 | 8.51 | 8.53 | 8.53 | 44.3 | 44.6 | 44.9 | 44.6 | 4.0 | 6.0 | 18 | 20 |
| 2 | 9.00 | 1 | 40 | 70.5 | 70.8 | 71.0 | 70.8 | 7.85 | 7.81 | 7.83 | 7.83 | 46.0 | 46.0 | 45.9 | 46.0 | 6.0 | 6.0 | 30 | 30 |
| 2 | 9.00 | 1 | 38 | 68.0 | 68.0 | 68.0 | 68.0 | 8.50 | 8.48 | 8.49 | 8.49 | 45.0 | 45.2 | 45.3 | 45.2 | 6.0 | 6.0 | 33 | 37 |
| 2 | 9.00 | 1 | 38 | 67.5 | 67.8 | 68.0 | 67.8 | 8.97 | 8.98 | 8.98 | 8.98 | 44.2 | 44.3 | 44.3 | 44.3 | 1.0 | 6.0 | 20 | 24 |
| 2 | 9.00 | 1 | 40 | 72.5 | 72.8 | 73.0 | 72.8 | 10.55 | 10.49 | 10.52 | 10.52 | 45.3 | 45.2 | 45.1 | 45.2 | 6.0 | 6.0 | 32 | 31 |
| 2 | 9.00 | 1 | 39 | 69.5 | 70.0 | 70.5 | 70.0 | 8.26 | 8.29 | 8.28 | 8.28 | 45.5 | 45.4 | 45.2 | 45.4 | 0.5 | 6.0 | 29 | 31 |
| 2 | 6.00 | 2 | 37 | 65.5 | 65.8 | 66.0 | 65.8 | 6.18 | 6.22 | 6.20 | 6.20 | 41.9 | 42.0 | 42.0 | 42.0 | 2.0 | 5.5 | 16 | 19 |
| 2 | 6.00 | 2 | 39 | 70.5 | 70.3 | 70.0 | 70.3 | 8.25 | 8.23 | 8.24 | 8.24 | 44.5 | 44.5 | 44.4 | 44.5 | 4.0 | 5.0 | 22 | 21 |
| 2 | 6.00 | 2 | 40 | 68.5 | 69.0 | 69.5 | 69.0 | 7.59 | 7.60 | 7.60 | 7.60 | 43.5 | 43.5 | 43.5 | 43.5 | 1.0 | 5.0 | 23 | 33 |
| 2 | 6.00 | 2 | 40 | 66.5 | 66.3 | 66.0 | 66.3 | 7.05 | 7.04 | 7.05 | 7.05 | 43.0 | 43.1 | 43.1 | 43.1 | 4.0 | 5.0 | 24 | 32 |
| 2 | 6.00 | 2 | 40 | 68.0 | 68.0 | 68.0 | 68.0 | 8.33 | 8.29 | 8.31 | 8.31 | 44.1 | 44.2 | 44.2 | 44.2 | 4.0 | 5.0 | 27 | 30 |
| 2 | 6.00 | 2 | 41 | 69.5 | 69.8 | 70.0 | 69.8 | 8.25 | 8.23 | 8.24 | 8.24 | 45.2 | 45.3 | - | 45.3 | 2.0 | 3.0 | 23 | 24 |
| 2 | 6.00 | 2 | 41 | 68.0 | 68.3 | 68.5 | 68.3 | 7.41 | 7.43 | 7.42 | 7.42 | 42.1 | 42.1 | 42.0 | 42.1 | 6.0 | 6.0 | 16 | 18 |
| 2 | 6.00 | 2 | 40 | 67.5 | 67.5 | 67.5 | 67.5 | 6.68 | 6.76 | 6.72 | 6.72 | 43.0 | 43.0 | 42.9 | 43.0 | 6.0 | 6.0 | 29 | 39 |
| 2 | 6.23 | 2 | 40 | 66.0 | 66.5 | 67.0 | 66.5 | 7.18 | 7.17 | 7.18 | 7.18 | 42.2 | 42.2 | 42.2 | 42.2 | 6.0 | 6.0 | 21 | 24 |

| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 6.23 | 2 | 38 | 67.5 | 67.8 | 68.0 | 67.8 | 8.20 | 8.19 | 8.20 | 8.20 | 43.0 | 43.0 | 42.9 | 43.0 | 4.0 | 5.5 | 22 | 20 |
| 2 | 9.00 | 2 | 39 | 75.0 | 75.0 | 75.0 | 75.0 | 10.96 | 10.96 | 10.96 | 10.96 | 45.7 | 45.8 | 45.9 | 45.8 | 4.0 | 6.0 | 29 | 29 |
| 2 | 9.00 | 2 | 40 | 73.0 | 72.8 | 72.5 | 72.8 | 8.56 | 8.58 | 8.57 | 8.57 | 44.6 | 44.5 | 44.3 | 44.5 | 0.0 | 5.0 | 21 | 25 |
| 2 | 9.00 | 2 | 37 | 70.5 | 70.0 | 69.5 | 70.0 | 9.36 | 9.31 | 9.34 | 9.34 | 48.8 | 48.6 | 48.4 | 48.6 | 5.0 | 6.0 | 26 | 29 |
| 2 | 9.00 | 2 | 40 | 79.0 | 79.0 | 79.0 | 79.0 | 14.77 | 14.72 | 14.75 | 14.75 | 48.6 | 48.6 | 48.6 | 48.6 | 6.0 | 6.0 | 40 | 51 |
| 2 | 9.00 | 2 | 42 | 71.0 | 71.0 | 71.0 | 71.0 | 8.96 | 8.94 | 8.95 | 8.95 | 46.2 | 46.3 | 46.3 | 46.3 | 6.0 | 6.0 | 28 | 35 |
| 2 | 9.00 | 2 | 38 | 72.0 | 71.8 | 71.5 | 71.8 | 8.06 | 8.05 | 8.06 | 8.06 | 43.5 | 43.5 | 43.4 | 43.5 | 0.0 | 4.0 | 35 | 40 |
| 2 | 9.00 | 2 | 40 | 71.0 | 71.3 | 71.5 | 71.3 | 8.51 | 8.49 | 8.50 | 8.50 | 45.9 | 45.9 | 45.9 | 45.9 | 3.0 | 3.0 | 22 | 25 |
| 2 | 9.23 | 2 | 40 | 75.0 | 75.5 | 76.0 | 75.5 | 9.76 | 9.77 | 9.77 | 9.77 | 47.1 | 47.0 | 46.9 | 47.0 | 4.0 | 6.0 | 35 | 38 |
| 2 | 9.47 | 2 | 40 | 71.0 | 70.8 | 70.5 | 70.8 | 8.26 | 8.31 | 8.29 | 8.29 | 45.9 | 45.9 | 45.9 | 45.9 | 1.0 | 6.0 | 32 | 37 |
| 2 | 9.70 | 2 | 40 | 72.5 | 72.5 | 72.5 | 72.5 | 7.56 | 7.58 | 7.57 | 7.57 | 44.8 | 44.7 | 44.6 | 44.7 | 9.0 | 6.0 | 31 | 38 |
| 1 | 12.00 | 1 | 40 | 80.0 | 80.3 | 80.5 | 80.3 | 12.18 | 12.62 | 12.40 | 12.40 | 48.2 | 48.1 | 48.0 | 48.1 | 8.0 | 8.0 | 22 | 24 |
| 1 | 12.00 | 1 | 37 | 74.5 | 74.3 | 74.0 | 74.3 | 10.18 | 10.24 | 10.21 | 10.21 | 44.3 | 44.3 | 44.2 | 44.3 | 0.0 | 6.0 | 22 | 30 |
| 1 | 13.00 | 1 | 37 | 82.0 | 82.5 | 83.0 | 82.5 | 10.58 | 10.85 | 10.72 | 10.72 | 44.5 | 44.3 | 44.0 | 44.3 | 0.0 | 6.0 | 27 | 28 |
| 1 | 13.00 | 1 | 40 | 76.0 | 76.3 | 76.5 | 76.3 | 11.50 | 11.00 | 11.25 | 11.25 | 49.0 | 49.3 | 49.5 | 49.3 | 0.8 | 6.0 | 26 | 32 |
| 1 | 17.00 | 1 | 38 | 79.0 | 79.0 | 79.0 | 79.0 | 9.41 | 9.47 | 9.44 | 9.44 | 46.7 | 46.7 | - | 46.7 | 6.0 | 6.0 | 28 | 27 |
| 1 | 17.00 | 1 | 39 | 84.0 | 84.0 | 84.0 | 84.0 | 12.04 | 12.04 | 12.04 | 12.04 | 49.5 | 49.5 | 49.5 | 49.5 | 3.0 | 3.0 | 41 | 38 |
| 1 | 17.00 | 1 | 39 | 78.5 | 78.8 | 79.0 | 78.8 | 9.75 | 9.77 | 9.76 | 9.76 | 46.1 | 46.3 | 46.4 | 46.3 | 8.0 | 8.0 | 32 | 32 |
| 1 | 18.00 | 1 | 40 | 79.0 | 79.0 | - | 79.0 | 9.00 | 9.03 | 9.02 | 9.02 | 46.0 | 46.0 | - | 46.0 | 5.5 | 5.5 | 23 | 27 |
| 1 | 14.00 | 2 | 42 | 77.0 | 77.3 | 77.5 | 77.3 | 9.00 | 9.13 | 9.07 | 9.07 | 47.3 | 47.4 | 47.4 | 47.4 | 6.0 | 6.0 | 26 | 30 |
| 1 | 17.00 | 2 | 39 | 85.0 | 85.0 | 85.0 | 85.0 | 12.34 | 12.34 | 12.34 | 12.34 | 48.0 | 48.1 | 48.2 | 48.1 | 4.0 | 4.0 | 41 | 38 |
| 2 | 12.00 | 1 | 38 | 75.0 | 75.3 | 75.5 | 75.3 | 10.00 | 10.50 | 10.25 | 10.25 | 44.2 | 44.5 | 44.8 | 44.5 | 6.0 | 6.0 | 23 | 24 |
| 2 | 12.00 | 1 | 40 | 77.5 | 77.3 | 77.0 | 77.3 | 11.30 | 11.25 | 11.28 | 11.28 | 45.5 | 45.6 | 45.7 | 45.6 | 6.0 | 6.0 | 26 | 32 |
| 2 | 12.00 | 1 | 40 | 73.5 | 73.8 | 74.0 | 73.8 | 8.25 | 8.23 | 8.24 | 8.24 | 44.8 | 44.8 | 44.7 | 44.8 | 0.5 | 6.0 | 26 | 33 |
| 2 | 12.00 | 1 | 41 | 72.0 | 72.3 | 72.5 | 72.3 | 7.70 | 7.68 | 7.69 | 7.69 | 44.4 | 44.5 | 44.5 | 44.5 | 6.0 | 6.0 | 29 | 30 |
| 2 | 12.00 | 1 | 37 | 75.5 | 75.5 | 75.5 | 75.5 | 8.80 | 8.77 | 8.79 | 8.79 | 45.0 | 45.0 | 45.0 | 45.0 | 6.0 | 6.0 | 35 | 33 |
| 2 | 12.00 | 1 | 40 | 73.0 | 72.8 | 72.5 | 72.8 | 7.67 | 7.69 | 7.68 | 7.68 | 45.6 | 45.6 | 45.6 | 45.6 | 0.8 | 6.0 | 19 | 20 |
| 2 | 13.00 | 1 | 40 | 71.0 | 71.0 | 71.0 | 71.0 | 8.71 | 8.74 | 8.73 | 8.73 | 45.5 | 45.4 | 45.3 | 45.4 | 7.0 | 7.0 | 23 | 27 |
| 2 | 18.00 | 1 | 38 | 83.0 | 82.8 | 82.5 | 82.8 | 10.90 | 10.84 | 10.87 | 10.87 | 45.5 | 45.5 | - | 45.5 | 6.5 | 5.0 | 24 | 29 |
| 2 | 18.00 | 1 | 40 | 86.0 | 86.0 | 86.0 | 86.0 | 12.08 | 12.11 | 12.10 | 12.10 | 47.6 | 47.7 | 47.7 | 47.7 | 2.0 | 4.0 | 25 | - |
| 2 | 18.00 | 1 | 39 | 77.0 | 77.3 | 77.5 | 77.3 | 10.30 | 10.28 | 10.29 | 10.29 | 46.7 | 46.6 | 46.5 | 46.6 | 2.0 | 3.0 | 26 | 27 |
| 2 | 18.00 | 1 | 40 | 80.0 | 80.0 | 80.0 | 80.0 | 11.09 | 11.07 | 11.08 | 11.08 | 47.8 | 47.8 | 47.8 | 47.8 | 4.0 | 6.0 | 24 | 27 |

| | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 18.00 | 1 | 40 | 77.0 | 77.5 | 78.0 | 77.5 | 10.46 | 10.41 | 10.44 | 10.44 | 45.0 | 45.0 | 45.0 | 45.0 | 0.0 | 4.0 | 27 | 33 |
| 2 | 12.00 | 2 | 40 | 75.0 | 75.5 | 76.0 | 75.5 | 9.70 | 9.73 | 9.72 | 9.72 | 46.4 | 46.5 | 46.6 | 46.5 | 6.0 | 6.0 | 25 | 34 |
| 2 | 12.00 | 2 | 40 | 77.0 | 77.0 | 77.0 | 77.0 | 9.23 | 9.27 | 9.25 | 9.25 | 46.4 | 46.6 | 46.8 | 46.6 | 3.0 | 4.5 | 39 | 43 |
| 2 | 12.00 | 2 | 40 | 76.0 | 76.3 | 76.5 | 76.3 | 9.42 | 9.39 | 9.41 | 9.41 | 46.0 | 46.1 | - | 46.0 | 0.0 | 5.5 | 26 | 35 |
| 2 | 12.00 | 2 | 40 | 75.5 | 75.8 | 76.0 | 75.8 | 9.20 | 9.23 | 9.22 | 9.22 | 46.7 | 46.8 | 46.8 | 46.8 | 1.0 | 5.0 | 21 | 23 |
| 2 | 12.00 | 2 | 40 | 70.5 | 70.8 | 71.0 | 70.8 | 8.82 | 8.76 | 8.79 | 8.79 | 46.4 | 46.3 | 46.2 | 46.3 | 5.0 | 5.0 | 32 | 39 |
| 2 | 12.00 | 2 | 40 | 79.0 | 79.3 | 79.5 | 79.3 | 12.30 | 12.33 | 12.32 | 12.32 | 47.6 | 47.8 | 48.0 | 47.8 | 6.0 | 6.0 | 40 | 35 |
| 2 | 12.23 | 2 | 40 | 81.0 | 81.3 | 81.5 | 81.3 | 12.10 | 12.14 | 12.12 | 12.12 | 49.0 | 48.9 | 48.8 | 48.9 | 7.0 | 7.0 | 30 | 30 |
| 2 | 15.00 | 2 | 40 | 79.0 | 79.0 | 79.0 | 79.0 | 9.13 | 9.15 | 9.14 | 9.14 | 45.3 | 45.4 | 45.4 | 45.4 | 5.0 | 5.0 | 17 | 22 |
| 2 | 18.00 | 2 | 42 | 88.0 | 87.5 | 87.0 | 87.5 | 10.70 | 10.68 | 10.69 | 10.69 | 48.0 | 48.0 | 48.0 | 48.0 | 3.0 | 4.0 | 32 | 25 |
| 2 | 18.00 | 2 | 40 | 79.0 | 78.8 | 78.5 | 78.8 | 10.02 | 10.05 | 10.04 | 10.04 | 48.2 | 48.2 | 48.1 | 48.2 | 3.0 | 1.0 | 23 | 27 |
| 2 | 18.00 | 2 | 40 | 79.5 | 79.3 | 79.0 | 79.3 | 10.20 | 10.22 | 10.21 | 10.21 | 46.6 | 46.7 | 46.7 | 46.7 | 8.0 | 9.0 | 27 | 29 |
| 2 | 18.00 | 2 | 40 | 81.0 | 81.0 | 81.0 | 81.0 | 11.12 | 11.09 | 11.11 | 11.11 | 51.0 | 50.5 | 50.0 | 50.5 | 11.0 | 6.0 | 19 | 22 |
| 2 | 18.00 | 2 | 37 | 87.0 | 86.8 | 86.5 | 86.8 | 13.54 | 13.51 | 13.53 | 13.53 | 47.8 | 47.8 | 47.8 | 47.8 | 3.0 | 4.0 | 26 | 25 |