YOUTH FITNESS TESTING IN SOUTH AFRICAN PRIMARY SCHOOL CHILDREN: NATIONAL NORMATIVE DATA, FITNESS AND FATNESS, AND EFFECTS OF SOCIOECONOMIC STATUS

By

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This thesis is dedicated to:

Winston Donovan Robinson

18/10/1924 – 30/04/2008

Train up a child in the way he should go,
And when he is old he will not depart from it.
Prov 22:6

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Declaration

I, Miranda Elaine Glynis Armstrong, hereby declare that the work on which this dissertation is based is my original work (except where acknowledgments indicate otherwise) and that neither the whole work nor any part of it has been, is being, or is to be submitted for another degree in this or any other university.

I empower the university to reproduce for the purpose of research either the whole or any portion of the contents in any matter whatsoever, baring the use of the software developed for this project for financial gain.

Signed: ___________________________________

Date: ___________________________________

Publications

Peer reviewed publications related to this thesis

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Abbreviations

AAHPERD (American Alliance for Health, Physical Education, Recreation and Dance)
BF (Body fat)
BMI (Body mass index)
CI (Confidence interval)
CVD (Cardiovascular disease)
cm (centimetre)
CDC (Centres for Disease Control and Prevention)
CHD (Coronary heart disease)
DEXA (Dual-energy X-ray absorptiometry)
GUI (Graphical user interface)
IOTF (International Obesity task Force)
JAD (Joint Application Development)
kg (kilogram)
MRC (Medical Research Council)
m (meter)
n (number of subjects)
NHANES (National Health and Nutrition Examination Survey)
NCHS (US National Centre for Health Statistics)
NIR (Near infrared interactance)
OR (Odds ratio)
RAD (Rapid Application Development)
SA (South Africa)
SD (Standard deviation)
USA (United States of America)
WHO (World Health Organization)

Abstract

Overweight, obesity and declining levels of physical fitness have been identified as a problem in many developed countries (1). More recently concern has been raised as a result of the rapid increase in the prevalence rates of overweight and obesity in developing nations ((2); (3); (4); (5)). However, little information is available at a national level for South African primary school children.

In this thesis, the current nutritional status and baseline measures of physical fitness are established for a large and representative sample of South African primary school children from a range of ethnic and socioeconomic groups. Interactions between nutritional factors and physical fitness are also considered. Further to this, differences between the anthropometry, nutritional status and physical fitness of children from different socioeconomic statuses are examined.

The first study aimed to determine the prevalence of under- and over-nutrition in a large sample (n = 10295, 5611 male and 4584 female) of South African children (6 to 13 years). Children from at least five different schools in each of five South African Provinces were sampled. The study design consisted of random sampling within each provincial and socioeconomic category and a cluster-like design within each school. Height and weight were measured in the South African Discovery Vitality Health of the Nation Survey (2001 to 2004). The WHO 2007 (6) and the 1978 CDC/WHO (7) references were used to calculate the prevalence of mild and moderate stunting, wasting, co-prevalence of stunting and wasting, and underweight for each group (age x gender x ethnic group). Percentile measures of body mass index (weight (kg) / height $(m)^2$) for each grouping (age x gender x ethnic group) were used to predict the prevalence of overweight and obesity. Age- and gender-specific cut-off points for body mass index were derived in accordance with the international standards derived by Cole et al. (2000). These cut-points were based on international cross-sectional data, used to predict those subjects who would be overweight (BMI of 25 $kg.m^{-2}$) and obese (BMI of 30 $kg.m^{-2}$) at the age of 18 years. The variation in prevalence of overweight and obesity according to gender, age and ethnicity was also considered.

The black children had the highest prevalence of both mild and moderate stunting. Mixed ancestry children had the highest prevalence of wasting. The co-prevalence of stunting and wasting was low in all ethnic and gender groups. Although white children had the lowest levels of underweight they also had the highest prevalence of overweight and obesity. When compared to previous South African data, under-nutrition (barring wasting prevalence) has decreased considerably over the decade preceding this study. However, overweight and obesity prevalence have increased at an alarming rate in the same time period, with South African children now showing prevalence rates for overweight and obesity similar to those values noted in developed countries about ten years ago. Suitable intervention strategies should be introduced to curb further increases in over-nutrition among young South Africans.

The main objective of the second study was to describe the physical fitness levels, by age (6 to 13 years), gender and ethnicity, in a representative sample of South African primary school children. The same sample and study design were used as in the first study. Standing long jump, shuttle run, sit-and-reach, sit-up (derived from the EUROFIT testing battery) and cricket ball throw scores were collected. These scores were used to assess the physical fitness levels of the children. The variation in physical fitness scores according to gender, age and ethnicity was also considered.

There were no differences in sit-and-reach flexibility test results between the groups. With the exception of the cricket ball throw for girls, white children had higher scores in most tests included in the testing battery. Although not significantly different from the white children, in the majority of cases the children of mixed ancestral origin had scores which ranged between the other two ethnic groups. Disparities were still evident after co-varying for anthropometrical differences between the ethnic groups. Overall, South African children performed similarly to their European counterparts of 10 to 15 years ago, except for number of sit-ups completed in 30s, which were fewer than those completed by European children in comparable data sets.

The third study described the interactions between nutritional status and physical fitness levels, again using the same sample and study design. Age and gender specific percentile scores were calculated for the nutritional and physical fitness variables assessed in the first two studies. The physical fitness performance of children classified as overweight or obese, mildly stunted, moderately stunted, wasted, or underweight was compared to children from the remainder of the sample. Differences in the prevalence of obesity and overweight between stunted and non-stunted children were also assessed.

Overweight and obese children produced lower scores on all of the fitness tests, with the exception of the cricket ball throw, for which they performed on par with the other children. Mildly and moderately stunted and underweight children were unable to match the performance of the remainder of the group on the majority of the tests of physical fitness. The performance of wasted children was not as highly compromised as that of the other undernourished groups; in fact they performed better than normal weight children on the standing long jump test. There was no significant difference between the prevalence of overweight and obesity in stunted verses non-stunted children, although non-stunted children had consistently higher values for over-nutrition. The results from this study indicate that South Africa is now in the later middle stages of the nutritional transition. As such it is important to use a duel approach, promoting interventions which address both under- and over-nutrition.

The final study aimed to describe the effects of socioeconomic status on nutritional indicators and physical fitness performance of the same group of children, according to age (6 to 13 years), gender and ethnicity. Comparisons were made between the anthropometric, nutritional and physical fitness scores of children from the highest and lowest socioeconomic groups (age x gender x socioeconomic x ethnic group). Results showed that children from high socioeconomic status were usually taller, weighed more and had a higher BMI than children from low socioeconomic status. Children from the lowest socioeconomic group had higher levels of mild and moderate stunting when compared to those from the highest socioeconomic group. With the exception of mixed ancestry girls, the occurrence of wasting, stunting and wasting, and underweight were generally higher in the lowest socioeconomic group. High socioeconomic status children had the highest overweight and obesity prevalence, with black children displaying the highest levels of obesity. Flexibility scores were similar between high and low socioeconomic status children; however children from high socioeconomic status performed better than low socioeconomic status children on the standing long jump and sit-up tests. Although some differences were evident between the shuttle run scores of children from different socioeconomic status, which group completed the test in the shortest amount of time was dependant on age. The cricket ball throw for distance, showed no consistent socioeconomic differences between the different gender and ethnic groupings.

In conclusion, the anthropometric, nutritional and physical fitness characteristics of South African children are still affected by South Africa's political history. Secular trends indicate improvements in the majority of the indicators of under-nutrition; however, these data suggest that there has been a dramatic increase in the prevalence of overweight and obesity. Findings from this thesis indicate that South Africa is in the later middle stage of a nutritional transition and therefore intervention strategies should be developed and implemented which focus on both over- and under-nutrition.

CHAPTER 1

THE PROBLEM

1.1 Introduction

South Africa is a country currently experiencing political, social and economic transition as it moves from an authoritarian to a democratic state (8). Despite its classification as a Middle-Income country (9), a history of colonialism and apartheid has left its mark in the form of an economy characterised by a mixture of First and Third World conditions (8). The large disparity between rich and poor is manifest in both demographic and epidemiological challenges resulting in at least a double burden of disease. As expected in a developing country, poverty and underdevelopment have given rise to the spread of numerous infectious diseases, in particular, TB and HIV/AIDS. Concurrently, the high rate of industrialisation and urbanisation has facilitated a rise in chronic disease ((10); (8)).

In the past it has been assumed that the physically demanding way of life experienced by children in developing countries resulted in a natural standard of physical fitness which obviated the need for organised physical education and school-based sports programmes. Yet, with transition and an increased focus on the introduction of technology and industrialisation, this argument loses its relevance, especially among children based in urban areas (11).

1.2 Nutritional status and physical fitness of young South Africans

Results from the South African National Youth Risk Behaviour Survey (8) indicated a national prevalence of underweight of 9% amongst grade 8 to 11 learners, with stunting affecting 11% and wasting 4% of learners. Boys were affected to a greater degree than girls in all of these conditions. Differences were noted for children from different ethnic groups, with black children and those of mixed ancestry[1] more likely to be underweight[2], stunted[3] or wasted[4], compared to white children. Under- and over-nutrition in adolescents were juxtaposed with 17% of learners considered overweight and 4% obese. Significantly more girls than boys were overweight and obese. With respect to possible causative factors, 29% of learners reported that they had no physical education classes at school and 25% watched more than three hours of television per day (8).

The National Food Consumption Survey (12) provides insight into the nutritional status of South African preschool and young primary school children during the mid 1990's. Stunting was prevalent in approximately 22% of 1 to 9 year old children. Stunting prevalence decreased with increasing age. Twenty-six percent of children up to 3 years of age were stunted, decreasing to 21% in 4 to 6 year olds and 13% in 7 to 9 year olds. Underweight prevalence showed a less marked downward trend with age; with 13%, 9% and 8% of children classified as underweight respectively. Wasting was less than 4% across all of the age groups. Six percent of children who participated in this survey were classified as overweight.

The nutritional status of 8 to 11 year old South African children from the Kwa-Zulu Natal province during this same time period was examined by Jinabhai et al. (10). The primary source of data was from a rural KwaZulu-Natal community-based survey and included 802, 8 to 11 year old children. The secondary source of data was an extract from a national primary school survey, and included only those children from the province of KwaZulu-Natal (N= 24 391). In this sample, 28% of boys and 21% of girls were stunted. According to the International Obesity task Force (IOTF) definitions (13), 2.3% were overweight, with 0.4% classified as obese. The World Health Organisation (WHO) classifications (14) showed an overweight prevalence of 3.4% and obesity level of 0.8%. The co-prevalence of overweight/obesity and stunting is also of concern. An examination of this co-

[1] A uniquely South African group referring to those of mixed origin, including people previously referred to as "Cape Coloured" within the classical literature.
[2] A weight-for-age Z-score below -2 SD of a given reference population
[3] A height-for-age Z-score below -2 SD of a given reference population
[4] A weight-for-height Z-score below -2 SD of a given reference population

prevalence in the same sample classified 25% of overweight, and 11% of obese boys as stunted according to IOTF definitions, fifteen percent of overweight and 10% of obese girls were also stunted according to the same definitions. The WHO classifications indicated that 23% of overweight, and 16% of obese boys; and 17% of overweight, and 14% of obese girls were stunted. The data, on which these nutritional values were based, was collected around the same time as the election of the first post-apartheid government into South Africa (1994). Since that time, government has been committed to addressing the health needs of marginalised groups, specifically woman and children suffering from poverty (15). Therefore, an examination of the prevalence of these nutritional conditions within the South African population assessed a decade later, will give an indication of the degree to which policy changes have been effective at the grassroots level.

Although there are no nationally representative data for the physical activity patterns of younger South African children, the Birth-to-Twenty study gives an indication of the situation in the Gauteng Province of South Africa (16). While black children spent an average of 29 minutes per week playing sport, white children spent 130 minutes. Physical education classes were offered to less than 33% of black children during school with 42% not participating in any formal sport. This can be compared to the 92% of white learners who participated in physical education classes. There were also differences in the time spent in "active" commuting where white children spent 2 minutes per day commuting compared to black children who spent an average of 19 minutes per day commuting (16). These activity levels are well below the recommended time for youth of 60 minutes of physical activity per day (17). Another editorial release (18), indicated that white children watched half as much television when compared to black children.

All of these differences are likely to have some adverse bearing on the physical fitness levels of South African children. However, there has been minimal research with respect to physical fitness levels in a representative group of young South Africans. A study conducted by Andrews (19) on the physical fitness of high school students is of limited value as it only considered white males. More recently, Monyeki (20) examined the physical fitness of 7 to 14 year boys and girls from the Ellisras area of South Africa, however, this study only considered a local, rural population of undernourished children.

From the above, it is evident that previous South African studies of the physical fitness of primary school age children have not considered a widely varied sample including children from many different geographical locations across South Africa. Therefore, no national baseline normative physical fitness data are available from a representative group of young South Africans against which comparisons may be made with international sample populations. This void in information is likely to have resulted at least in part, from a combination of the logistics, lack of prioritisation and high costs involved in large scale epidemiological studies of this nature.

1.3 **Aims and Objectives**

Therefore, the main aim of this thesis was to describe and investigate the health-related fitness of primary school children in South Africa. No baseline health-fitness data exists for an ethnically and socioeconomically diverse group of young South Africans. To best facilitate the creation of these norms, it was necessary to overcome the numerous barriers associated with large scale testing. Choosing a battery of repeatable fitness tests, easily conducted under varied conditions, with minimal equipment was therefore the first objective. This test battery then needed to be used in the collection of data from a representative group of South African children from which baseline normative values for physical fitness could be created. Following from this was an in-depth analysis of the data to answer ethnic and socioeconomic questions pertinent to South Africa as a country in transition. The final objective was to use this new information to automate the basic analysis of test results and provide readily understandable feedback in the form of a software package, thereby improving the likelihood and ease of future testing.

This led to the formulation of the following specific aims:

i) Choose an appropriate test battery that contains tests which are internationally recognised for comparative purposes. These tests need to be valid and repeatable in a large sample of children from diverse backgrounds, conducted in varied settings; while using minimal, inexpensive equipment;

ii) Assess the nutritional status, inferred from anthropometrical indicators, within a socioeconomically and ethnically varied sample of South African children between the ages of 6 and 13 years;

iii) Construct baseline physical fitness normative data for this sample of South African children;

iv) Investigate the interactions between nutritional status and physical fitness of this group of children;

v) Assess the relationship between socioeconomic status and nutritional status, as well as physical fitness of the same group of South African children;

vi) Compare the nutritional status and physical fitness of South African children to the same measurements collected from children in other countries;

vi) Create a software package to process, profile and rank the physical fitness characteristics of primary school children (6 to 13 years), according to South African normative data.

The findings of this thesis will have implications for the formulation of evidence-based guidelines for physical education within the South African primary school system. In addition this dissertation will also provide information which may contribute to designing intervention strategies for specific population groups within South Africa with respect to physical activity.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter gives an overview of the main concepts considered in this dissertation, with an ultimate aim of providing an evidence-based physical fitness test battery for use in a large group of South African primary school children. Nutritional conditions associated with under- and over-nutrition and adverse early life environments were considered. This information was used to choose an appropriate method of assessment for the nutritional status of young South Africans. Secondly, physical fitness, health and health-related fitness are discussed. The section introduces the different components of physical fitness, focusing on health-related fitness, and considers the reliability and validity of common tests used to assess these components. This information is then considered in the choice of appropriate tests for inclusion in a test battery specifically for use with a large, ethnically and socioeconomically diverse group of young South Africans. An overview of the interactions between nutritional status and physical fitness of children follows this section. The literature review concludes with comments on the effects of the perceived differences in nutritional status and physical fitness of children, according to different ethnic and socioeconomic groups.

2.2 Nutritional Disorders

While wasting has been almost completely eliminated in many developing countries, stunting still remains a problem (21). Urbanization and poor screening for inclusion in nutritional supplementation programmes are thought to be the main causes of the co-existence of conditions associated with lack of nutritional resources and those associated with excess ((10); (22)). Within South Africa, studies have shown that poor families experiencing industrialization in urban areas are at a high risk for developing nutritional disorders. Indeed, conditions associated with both over- and under-nutrition may exist simultaneously in the same household ((23); (24)).

2.2.1 **Conditions associated with poverty and under-nutrition**

Lack of food and repeated bouts of disease reflect the presence of poor nutrition within a community. These are in turn determined by: ease of access to food, fundamental education, caring capacity, local health infrastructures, housing and environment (see Figure 1) (25).

Two of the main nutritional states associated with lack of nutritional resources are malnutrition and under-nutrition. Malnutrition results from an incorrect balance between required and consumed diet, with respect to the nutrients essential to maintain health. It may be the consequence of under-nourishment but can also refer to an imbalance in basic foodstuffs or even dietary excess ((26); (27)). Under-nourishment is a common cause of death within third world countries (28). In contrast, under-nutrition is a condition common in developing countries, which results from consuming insufficient food over a period of time. It often leads to reduced mental and physical capacity and a decreased resistance to disease.

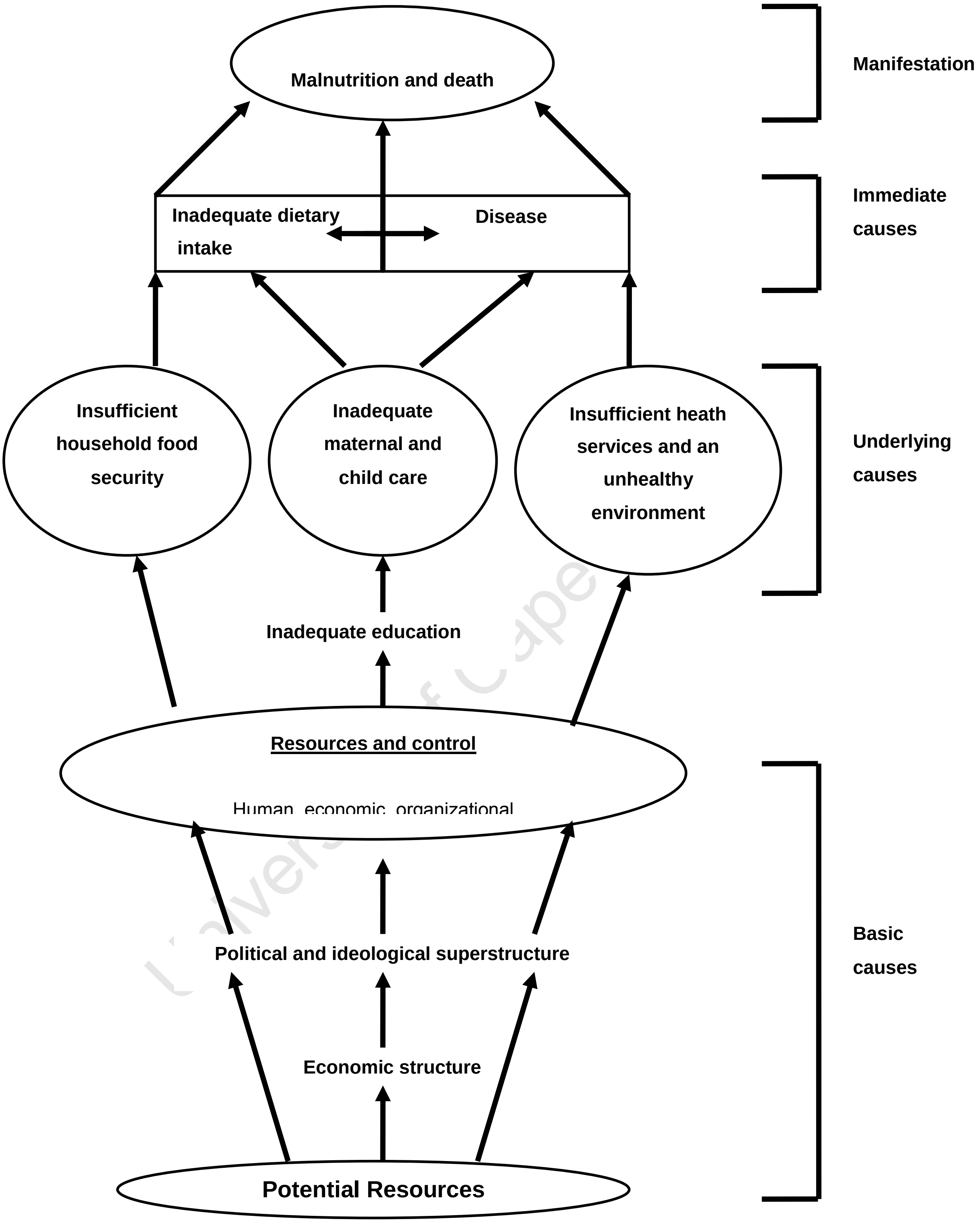

Figure 1: The multiple causes of malnutrition and death (Source, (29))

2.2.1.1 **Underweight, stunting and wasting prevalence among South African youth**

The South African National Youth Risk Behaviour Survey (8) and the National Food Consumption Survey (12) indicated that the prevalence of wasting was low at 4% or less, in both children and adolescents. Levels of underweight decreased with increasing age. Twenty-six percent of one to three year old children were underweight, while only 9% of high school children were underweight. The prevalence of stunting also decreased with an increase in age, with 22% of 1 to 9 year olds and 11% of grade 8 to 11 learners stunted.

From these surveys, it is evident that nutritional conditions associated with lack remain a problem in South Africa, even over the past two decades, especially among pre-primary and primary school children. Although the prevalence of wasting was low, levels of underweight and stunting were still of concern. Since this time, South Africa has undergone much change which may have had an effect on the multi-variate causation of these conditions. Whether this is the case still needs to be examined.

2.2.1.2 **Anthropometric assessment of nutritional indicators in children**

Jelliffe (30) defined nutritional anthropometry as *'measurements of the variations of the physical dimensions and the gross composition of the human body at different age levels and degrees of nutrition'*. It has been accepted internationally as a general indicator of child growth and development, affected by both dietary intake and the health of the individual (31). Gibson (32) proposed a number of advantages associated with the use of nutritional anthropometric assessment, although there are also limitations. These are explored in Table I.

The height and weight measurements of children are normally cited in terms of z-scores, derived from the standard deviations above and below the median reference value for a person at a specific age. The value at the median -2 SD of the reference population is usually accepted as the cut-off point below which malnutrition is present (33).

Table I: The advantages and limitations of nutritional anthropometry (Adapted from (32); (34)).

Advantages	Limitations
• Methods are precise and accurate, provided standardized techniques are used, • Procedures use simple, safe and non-invasive techniques • Equipment required is inexpensive, portable and durable, and can be made or purchased locally • Relatively unskilled personnel can perform measurement procedures • Information is generated on past nutritional history • Methods can be used to quantify the degree of under-nutrition (or over-nutrition) and provide a continuum of assessment from under-to over-nutrition • Methods are suitable for large sample sizes such as representative population samples • Methods can be used to monitor and evaluate changes in nutritional status over time, seasons, generations, etc. • Methods can be adopted to develop screening tests in situations such as nutritional emergencies to identify those at high risk	• The relative insensitivity to detect changes in nutritional status following inadequacy of food over short periods of time • The inability to distinguish the effect of specific nutrient deficiencies (e.g. zinc deficiency) that affect growth in children from that due to inadequacy of food in general • The inability to pinpoint the principal causality of under-nutrition, as the poor nutritional status may be the result of factors such as repeated insults owing to infections and poor care in children • The relative higher costs and organization required to obtain representative and quality data for the purpose of estimating numbers of undernourished

Underweight is defined as a weight-for-age z-score below -2 SD of the reference population (25). It gives an index of the adequacy of the child's nutrition to support growth (27). However, no differentiation may be made between chronic and acute deficiencies. Underweight is most commonly applied in national and regional statistics (25). However, the use of weight-for-age in monitoring growth past 10 years of age is not recommended as this measure is unable to distinguish between the relationship of height to body mass (35).

Stunting or growth retardation often results in lifelong short stature (27). It is described as a height-for-age z-score below -2 SD of the reference population and suggests long-term nutritional deprivation. Possible contributing factors include poverty, low socioeconomic status and chronic disease (25). It is often associated with inadequate protein intake (27) and it was postulated that protein-energy malnutrition affected more than half of children in developing countries during the early 1990s (36).

Stunting in children below five years of age reveals the lack of provision of basic needs during infancy and the preschool years and has thus been identified as an appropriate indicator of poverty in a population (25). The presence of stunting in children five years or older indicates a prior problem (34). Stunting which occurs in early childhood is not completely reversible, however a better diet may aid in improving the situation. In the long term, stunting impairs cognitive ability and leads to decreased productivity during adulthood (37).

Wasting gives an indication of acute malnutrition and is defined as a weight-for-height z-score below -2 SD of the reference population. This is related to hunger, insufficient food intake and food shortages (25). The equivalent measure in adolescents is a BMI value below the fifth percentile of the reference population (37).

Many malnourished children are of low weight- and height-for-age, while still displaying near normal weight-for-height, indicating that they are both underweight and stunted, but not wasted. Recovery in length/height-for-age is partial when nutritional improvements are supplied after 2 to 3 years of age. When children older than this are given a supplemented diet, gains in weight-for-age will be much greater than gains in height-for-age (22). This disparity is even more marked in older children and may result in the development of overweight or obesity (38). When stunting is severe, resulting in delayed bone age maturation, the effects of stunting are potentially more reversible (22).

2.2.1.3 **Consequences of poor nutrition**

Childhood development may be adversely affected if the mother's nutrition and health status is poor during pregnancy or lactation. Sub-optimal nutrient and energy intake during pregnancy usually leads to impeded growth resulting in low birth weight. This puts the child at a physical disadvantage which they may struggle to compensate for in later years ((39); (34)). Smaller body size and deficient growth have been associated with impaired mental development. A relationship has also been identified between school performance, intelligence and growth status (39).

A history of under-nutrition may limit work productivity during later life (34). An inadequately nourished person is at an increased risk for developing infections. This results in a negative downward spiral of under-nutrition and infection (40). Conversely, there is a growing body of evidence which proposes that stunted individuals are more likely to become overweight or obese than those of normal height-for-age if they are exposed to lifestyle changes which include increased food availability (41).

On the macro level, the economic consequences of under-nutrition in some countries are severe. It is proposed that at least half of the diseases in these countries are associated with malnutrition. Malnutrition has also been associated with a one percent reduction in the growth of the world economy (25).

2.2.1.4 Challenges with the use of nutritional data in adolescents

According to the WHO (42), adolescents refer to youth ranging in age from 10 to 19 years. When considered from an anthropometric perspective, young adolescents may be more similar to children, while elder adolescents show a greater similarity to adults (43). Therefore, an anthropometric assessment of nutritional status in this age group poses a number of challenges not present among younger children. These challenges include changes in the anthropometric body proportions with age, different rates of pubertal development and anthropometric differences between ethnic groups.

2.2.1.4.1 Changes in body proportion with age

One of the main problems associated with using anthropometric indices relates to changes in body proportions with age. Whereas, the weight-for-height index in children below five years is considered constant, weight-for-height and BMI change with age in school-age children and adolescents (44). The Cormic Index (sitting height divided by standing height) declines during childhood, but later increases with the onset of the adolescent growth spurt (45). These differences in indices with age imply that comparisons of different anthropometric indices should only be made with children of the similar age and maturity level (43).

2.2.1.4.2 Pubertal development

The second challenge of using anthropometric data as a measure of nutritional status is that of pubertal development. Changes resulting from pubertal development occur at a much faster rate than changes related to age (43). During the adolescent growth spurt the fastest rate of height gain directly precedes the fastest rate of weight gain (46). This results in an acceleration of the rate of increase of BMI shortly following peak height velocity. Therefore, this increase is as a result of pubertal development rather than an increase in chronological age ((46); (47)). According to Eveleth and Tanner (48), different populations display sexual development milestones at different ages. If these milestones are significantly different between the study and reference population, comparative results may be compromised. A second complication relates to chronic under-nutrition, which may delay the onset of sexual maturity and hence the adolescent growth spurt ((49); (50); (48)). These delays may need to be considered when comparing well-nourished reference populations with undernourished study populations.

2.2.1.4.3 **Ethnic differences**

Ethnic differences have been identified as a possible discriminator of anthropometric indices past puberty. Habicht et al. (51) stated that children of different nationalities below five years of age were of similar size and shape. However, Woodruff and Duffield (43), question whether this is the case in school age children and adolescents. They propose that older adolescents who have completed their growth spurt are essentially adults and will as such display the differences in Cormic Index which have been identified between different ethnic groups ((52); (53)). Differences in Cormic Index may have a substantial effect on BMI ((52); (53)), which questions the validity of comparing older adolescents with a single universal reference population (51).

2.3 Conditions associated with excess

Obesity has been defined as the excess accumulation of adipose tissue such that it impedes physical and psychological health (54). It has become a global health problem, affecting more than 1.3 billion adults, in both developed and developing countries ((1); (55); (56); (57)). In South Africa it has been suggested that urbanization (58) is associated with an increased risk of becoming overweight or obese ((59); (3)). Indeed, high levels of obesity have been identified among urbanized South Africans, black woman in particular ((58); (3); (60)).

2.3.1 **Obesity and overweight prevalence among South Africans**

The South African Demographic and Health Survey (3) showed that the prevalence of overweight and obesity among adult South Africans was high. The highest levels were noted among black women with almost 60% over-nourished. Half of women in the other ethnic groups were over-nourished. Black men showed the lowest levels of overweight and obesity, at 25%. Approximately 30% of mixed ancestry and Indian men and 54% of white men were classified as over-nourished. The South African National Youth Risk Behaviour Survey (8) reported overweight and obesity levels of grade 8 to 11 learners. Their findings indicated that 17% of learners were considered overweight and 4% were obese. These very high levels of over-nutrition among adult and moderately high levels of over-nutrition among adolescent South Africans is concerning. It has been postulated that the origins of over-nutrition may start in childhood (61), indicating the need to examine the levels of overweight and obesity among children.

Results from the National Food Consumption Survey (12) showed that six percent of children up to nine years of age were overweight in the mid 1990s. Eight to eleven year old children at the same time period showed low levels of over-nutrition (10), with 2.3% overweight and 0.4% obese according to the cut-off points proposed by the IOTF. Prevalence using the WHO reference (14) were slightly higher. Obese children comprised 0.8% of the sample and overweight children accounted for 3.4%.

These rates of over-nutrition are low, especially considering the high levels of adult and adolescent over-nutrition. However, the pre- and primary-school data were collected one-and-a-half decades ago raising the concern about the applicability of the data at present. A re-assessment of overweight among young South Africans may be advantageous in determining whether the high levels of over-weight and obesity noted in the Demographic and Health Survey of adults (3) is reflected as a growing problem among children and young adolescents.

2.3.2 The effects of urbanization in the South African population

The epidemiological transition and high levels of urbanization, especially among the black sector, which constitutes three-quarters of the South African population, have been identified as a causative factor relating to increased prevalence of overweight and diseases of lifestyle. Changes facilitated by the epidemiological transition may be outworked through alterations in diet, attitudes, lifestyle factors such as physical activity levels, or even result from difference in the physical environment.

Steyn et al. (62) reported that black people from the Cape Peninsula of South Africa, who had spent more time in an urban environment, tended to follow a less healthy lifestyle than their rural counterparts. They were also at an increased risk for chronic diseases of lifestyle such as moderately elevated levels of non-insulin dependant diabetes mellitus (63). Other studies have identified changes in dietary intake towards a less healthy eating pattern among the black ethnic group in South Africa. For example, since the 1940s fat intake has almost doubled and carbohydrate intake has increased by approximately 15% with respect to the proportion of total dietary intake ((64); (65)). A higher fat diet was noted specifically in women living in urban areas (66).

Negative effects of urbanization may be exacerbated through the cultural attitudes of the people group being assessed. Puoane et al. (67) found that black women tended to prefer an overweight body shape. Other researchers have also identified positive connotations associated with overweight within the African community. Mvo et al. (24) said that overweight was linked with happiness and affluence within this sector. Clark et al. (68) showed that obesity led to decreased stigmatization. In this group obesity reflected health and well-being, while thinness was associated with human immunodeficiency virus/AIDS. Among adolescent

South African girls exposed to a similar ‘school culture’, black and mixed ancestry girls still showed less body image dissatisfaction than white girls (69). Mciza et al. (70) considered the difference between perceived and desired body size in young girls (9 to 12 years of age). They reported that black girls were less dissatisfied with their body size than white girls. Despite these observations, having a tertiary education has been associated with a lower BMI in black women (3). Mechanisms by which this occurs may include an increased awareness of the link between over-nutrition and poor health or increased exposure to media which disseminates the western beauty ideal of thinness ((3); (71)).

Kruger et al. (66) demonstrated a link between levels of socioeconomic status and obesity in black South Africans. They noted that a higher income level, a proxy for urbanization, was associated with a 1.5-fold increase in the probability of being obese. Further to this, they found that woman who were more active were less likely to have a high BMI or waist circumference. Within developing communities, urbanization has been associated with lower levels of physical activity ((72);(73)). Low levels of physical activity have in turn been linked to risk factors associated with CHD in this South African demographic group such that inactive black men displayed elevated levels of fasting insulin. Inactive black women showed increased levels of fasting insulin and a number of other risk factors (74).

Alterations in the environment resulting from urbanization have been linked with over-nutrition. Gordon-Larsen et al. (75) postulated that the physical environment is related to physical activity levels and other behaviours which contribute to obesity. They found that low socioeconomic status among adolescents was related to decreased access to facilities which promoted physical activity. This in turn led to lower levels of physical activity and increased levels of overweight. Within South Africa, of those adolescents reporting no physical activity in the week prior to the administration of a physical activity questionnaire, 15.7% attributed their inactivity to lack of access to physical activity equipment and 7.0% reported avoiding physical activity as they felt unsafe in their surroundings (76).

2.3.3 **Obesity within the paediatric population**

The World Health Organization (77) has identified an increase in childhood obesity in developed countries, occurring at twice the rate of that in the adult population (78). Developing nations show the fastest rates of increase (79), with a high prevalence of childhood obesity reported in developing regions such as Latin-America (4). In fact, childhood and adolescent obesity has been identified as a significant public health challenge internationally ((80); (81)). This trend is of great concern as obesity is likely to track into adulthood and is a risk factor for the development of many diseases of lifestyle (61).

As early as the middle of last century a secular trend of increasing body weight was noted. For example, Roche (82) showed that between the 1950's and 1960's there was an increase of 0.8 kg at 10 years of age, 1.8 kg at 15 years of age, and 0.9 kg at 20 years of age,. This is further demonstrated among 9 year old boys, where the mean weight-to-height ratio increased over a similar period of time (83). As the weight-to-height ratio naturally increases with an increase in age, some of this change may have been attributed to accelerated maturation. However, it is likely that a considerable amount of these increases have occurred as a result of an unhealthy rise in body fat percentage, as an increase in subcutaneous fat tissue within the paediatric population has been identified, especially within the upper percentiles of different population groups ((83); (84); (85); (86); (87)).

The number of American children falling into the obese category is steadily increasing (88). For example, between 1963 and 1970 (NHES II, NHES III), 11.3% of 6 to 14 year old American children were classified as overweight according to the IOTF definitions. This prevalence rose to 12.7% in the early 1970s (NHANES I, 1971-1974), 14.5% in the late 1970s (NHANES II, 1976-1980) and finally 24.2% in the early 1990s (NHANES III, 1988-1994) (89).

Increasing levels of obesity among the youth is not unique to the United States of America. The prevalence of obesity and overweight combined, doubled among Australian children between the ages of 7 to 15 years from 1985 to 1995. The frequency of obesity alone tripled in the same period (90). This increase was greater than the increase measured between 1969 and 1985 in Australian children. Chinn and Rona (91) measured the prevalence of overweight and obesity among English and Scottish school children according to the definitions given by the IOTF. Between 1984 and 1994 they found an increase in overweight of 9.3% to 13.5% in English girls (increase 4.1%, 95% confidence interval; 2.4% to 5.9%) and 10.4% to 15.8% in Scottish girls (increase 5.4%, 95% confidence interval; 3.2% to 7.6%). English boys increased from 5.4% to 9.0% (increase 3.6%, 95% confidence interval; 2.3% to 5.0%) and Scottish boys from 6.4% to 10.0% (increase 3.6%, 95% confidence interval; 1.9% to 5.4%). Seven to nine year old French children showed an increased prevalence of overweight compared to previously published French data (92). According to the IOTF cut-offs, 18.1% were overweight and 3.8% were obese.

Kalies et al. (93) found an increase in the BMI levels in the upper percentiles of 5 to 6 year old children entering school in Bavaria in 1997 when compared to those children who entered school in 1982. Over this time period the overweight/obesity prevalence increased from 8.5/1.8% to 12.3/2.8%. These results are similar to those found in other European studies, but lower than the Australian and American data. Figure 2, gives an indication of the prevalence of overweight among children in a number of European countries, according to the IOTF definitions.

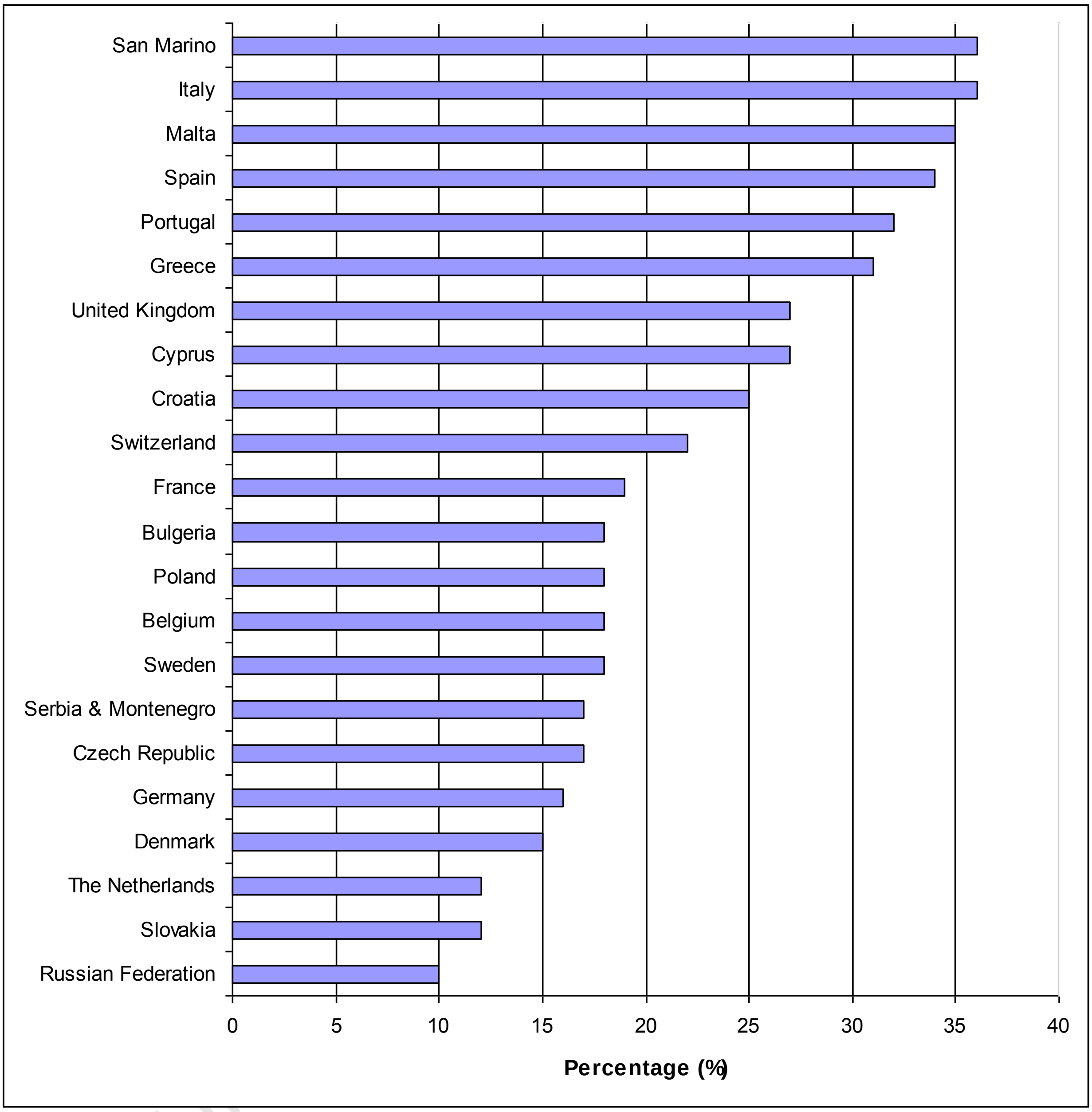

Figure 2: The prevalence of overweight children aged 7-11 years in 22 European countries (extracted from WHO 2005).

Increasing Overweight and Obesity levels have also been reported for children in developing nations (94), with the highest prevalence rates occurring in the children of the Middle Eastern, Central European and Eastern European regions (95).

Several studies have examined overweight and obesity prevalence in South American children. Neutzling et al. (96) showed that according to the CDC norms

(97) the prevalence of over-nutrition among Brazilian adolescents was 7.7%, with girls twice as likely to be overweight than boys. Although levels of overweight in Chilean 6 year olds was low in 2003 (2.2%), it had tripled since 1987 (0.7%) (98). Levels of over-nutrition in Eastern Europe were much higher. Half of 12 to 13 year old boys and one third of girls were obese (99).

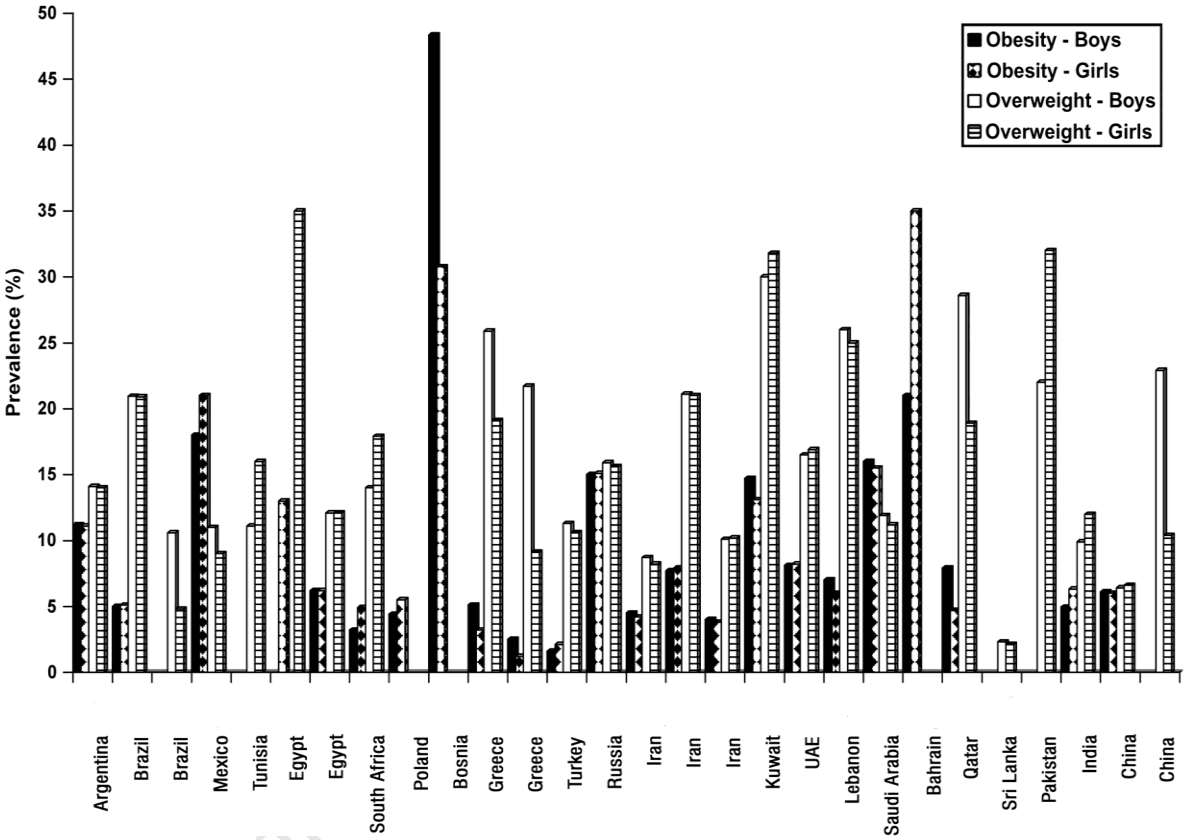

Figure 3: The prevalence of overweight/obesity in 6 to 18 year old boys and girls in developing nations (extracted from Kelishadi, 2007).

African countries show moderate levels of over-nutrition. One in ten adolescent Tunisian girls was at risk of becoming overweight in 2001 (100). Among Egyptian adolescents, 6.2% were obese and 12.1% were overweight, with girls showing twice the overweight prevalence of boys (101) according to the CDC normative curves (97).

Among Mediterranean countries, Greece and Turkey have reported over-nutrition statistics according to the IOTF cut-off points. Overweight prevalence was 15.4%, and obesity prevalence 1.9%, among Greek children (102), Even though obesity levels were the same among Turkish children, overweight prevalence was slightly lower at 11% (103).

Increasing levels of over-nutrition have been reported in Asian and Middle Eastern countries. For example, Thailand reported a 3% increase in obesity within the space of 2 years among primary school children (104). Among a similar age group in Japan, obesity levels doubled between 1974 and 1993, reaching 10% (105). Over a six year period, overweight prevalence doubled in Iranian children and adolescents (106).

High levels of over-nutrition were reported among young adolescent children from Kuwait. Overweight prevalence was 30.9% and obesity prevalence was 13.9% (107). According to IOTF definitions (13), obesity levels of 16.5% were reported among Bahraini school aged children (108). The same reference was used to show that 25.5% and 6.5% of 6 to 8 year old Lebanese children were overweight and obese respectively (109). Figure 3 shows the prevalence of overweight and obesity in school age children and adolescents from a number of developing countries.

2.3.4 Factors contributing to overweight and obesity in children

Poor nutrition and inactivity both affect body fatness. Globally, urbanization has led to decreased opportunities for childhood physical activity (110) to the degree that present societal norms now encourage inactivity among children due to television, computers and a lack of inbuilt physical activity during daily living ((111); (112)). In many cases the school environment has contributed to the problem. Schools no longer encourage children to lead physically active lifestyles and little attempt is made to protect children from poor dietary choices (113). It is proposed that this combination of inactivity and the increased availability of foods containing poor nutrition have resulted in the development of an environment which encourages overconsumption coupled with minimal physical activity ((114); (112)).

2.3.4.1 **Physical activity versus sedentary activity**

Television viewing has been associated with the onset of obesity and a decrease in its remission (112). The mechanisms by which this occurs are thought to be a combination of displacement of physical activity, increased calorie consumption while watching television and a reduction in the resting metabolic rate (115).

Robinson (116) used an educational programme administered by school teachers to reduce the amount of television, video-tape and video-game use among a group of junior school children. This programme did not target diet or physical activity. Results showed that increases in BMI and other measures of fatness over the test period were significantly lower (between P = 0.001 and P = 0.003, at the 95th confidence interval) in the intervention group when compared to the controls. Gortmaker et al. (117) used an educational programme with grade 6 and 7 ethnically diverse children. Apart from focusing on decreasing television viewing they also included dietary and exercise guidelines.

They discovered that although there was no difference between the intervention group of males and controls, the prevalence of obesity in the intervention group of females was reduced when compared to the controls (odds ratio, 0.47; 95% confidence interval, 0.24-0.93; P = .03). There was also a larger remission of obesity within the female intervention group compared to the controls (odds ratio, 2.16; 95% confidence interval, 1.07-4.35; P = .04). Results of this study showed that each hour of reduced television viewing, predicted a reduction in the prevalence of obesity within the group of children (odds ratio, 0.85; 95% confidence interval, 0.75-0.97; P = .02).

This finding is in agreement with the strong dose-response of increased television viewing with prevalence of overweight found previously in a group of 10 to 15 year olds (112). When viewing more than 5 hours of television per day, the odds of being overweight were 4.6 times greater (95% confidence interval, 2.2 to 9.6) than those children who watched 2 or less hours of television per day. Other studies by Crespo et al. (118) and Toyran et al. (119) report a similar link between television viewing and prevalence of overweight among children and adolescents in the United States, Turkey and China respectively. This dose-response relationship of television viewing to overweight and obesity prevalence is of concern among the young South African population as data from the Youth Risk Behaviours Survey (8) indicates that one quarter of young South Africans watch more than three hours of television per day. Cultural and ethnic factors also influence how television viewing affects physical activity levels. In fact, contrary to what would be expected, Lowry et al. (120) reported that there were higher levels of physical activity among black male youth who viewed more television.

2.3.4.2 **Food choice and eating patterns**

Within the past few decades, an increased availability of food has accompanied an increase in food advertising (121). Television advertising has been associated with an increase in dietary energy intake and higher fat consumption ((122); (123)). In fact, exposure to food advertising, specifically fast- or convenience foods, can shape the food choices of individuals towards higher-fat and more energy dense foods ((124); (125); (123); (126); (127); (128)).

Television viewing may be related to increased fat and energy consumption as people are prone to snack when watching television ((129); (130); (131)). Less self-monitoring with regard to the type and amount of food consumed during this activity is proposed as a contributing factor (121). A study considering food advertisements in South Africa, reported that more than half of the food advertised (55%) during children's television programmes was of poor nutritional quality. Forty-two percent related to food of good nutritional quality however, none of these advertisements were for fruit, vegetables or whole grains (132).

Food pricing has an effect on the types of food consumed ((133); (134)). Indeed, extensive changes in specific food prices may influence which foods are predominantly consumed within a population ((135); (136)). Studies have shown that lowering the price of food items, both healthy and unhealthy, are an effective means of increasing sales and consumption of these items ((135); (137); (138)).

2.3.4.3 **Pregnancy, birth and formula feeding**

Obesity during pregnancy is a risk factor with respect to the later development of obesity during childhood. Whitaker (139) showed that 2 to 4 year old children born to obese low-income mothers were more than twice as likely to be obese when compared to those born to normal weight mothers. An increased risk of developing childhood obesity was noted when pregnant mothers suffered from diabetes. This was most marked when the birth weight was high (140).

It is proposed that early lifetime events, such as foetal malnutrition, may influence disease risk in later life; known as the *"developmental origins of health and disease"* paradigm (141). Epidemiological studies have shown that babies with gestational insults resulting in small or disproportionate birth size or altered placental growth have elevated rates of type II diabetes, heart disease and hypertension during adulthood (142). It has been suggested that this increased risk of disease is most pronounced when there is a marked mismatch between the early developmental environment and the adulthood environment (141). Among South Africans, the identified high levels of under-nutrition among children when coupled with extreme over-nutrition among adults has been identified as a key factor which needs to be addressed for the long term prevention of CHD in this population (143).

Low birth weight is a risk factor for the later development of central obesity ((144); (145); (146); (147); (148)) and hence implies an increased risk of cardiovascular disease ((149); (150)). At the other end of the spectrum, a review by Parsons et al. (151) indicated a strong relationship between high birth weights and increased fatness. Rapid weight gain during the first few months of life has also been linked with an increased risk of being overweight or obese during childhood ((152); (153)). However, this should be viewed in the context of another study which showed that breast-feeding has a protective effect against the later development of overweight (154).

2.3.4.4 **Parental eating, physical activity habits and obesity**

Obesity within the youth is influenced by family environment. Hopper et al. (155) assessed the efficacy of a health-related fitness intervention study targeting both parents and their children in the areas of nutrition and exercise activities. Following the intervention, children from the treatment group scored significantly higher with respect to nutrition and exercise knowledge than the children from the control group. They also scored significantly lower on total dietary fat intake. Despite these seemingly positive changes there were no significant improvements in physiological measures such as blood cholesterol levels.

With respect to parental obesity it is hypothesised that both family environment and genetic factors contribute to childhood overweight ((156); (157); (158); (159)). Reilly et al. (160) showed that when compared to children of non-obese parents, those children with an obese father were at almost double the risk of becoming obese children. Children with an obese mother had a risk of childhood obesity greater than four times that of non-obese parents and children whose parents were both obese, were at a 10-fold increased risk of becoming obese during childhood (160). Dowda et al. (161) found that both males and females, between 8 and 16 years who had a parent who was overweight, were more likely to be overweight than those children whose parents were not overweight. The mechanisms by which this occurs may relate either to genetic influences, or overweight parents controlling the nutritional behaviours of their children or both factors ((162); (163)).

Parents may also influence the overweight and obesity of their children indirectly through activity-related parenting practices. Krahnstoever et al. (164) found that the daughters of parents who provided logistic support for physical activity or who explicitly modelled physical activity to their children, had higher levels of physical activity than girls without this support.

2.3.4.5 **Socioeconomic and Demographic factors**

There is no clear association between socioeconomic status in early life and its effect on childhood obesity levels. However, a strong link has been found between low socioeconomic status during childhood and increased prevalence of overweight during adulthood (151). With respect to directionality, an inverse relationship between obesity and socioeconomic status or education level has often been observed in developed countries. Therefore, obesity is increasingly associated with the poor (165). In contrast to these findings, Tremblay and Willms (166) showed that Canadian children, classified as having a high socioeconomic status, were more likely to be overweight or obese. This disparity was partially explained by differences in physical activity levels and sedentary behaviours.

In developing countries, children from a high socioeconomic status are most affected by over-nutrition. An increase in economic growth leads to greater amounts of disposable income, changes in diet and the adoption of a sedentary Western lifestyle, all factors which contribute to an increased prevalence of overweight (167).

Demographic factors may also affect overweight and obesity status, although how these factors interact and manifest will depend on the stage of demographic transition and urbanization of a given country. Developed countries such as the United States and New Zealand have reported higher levels of overweight and obesity in indigenous population groups when compared to children originating from Europe ((168); (169); (170); (171)). Yet, a study conducted in The Gambia, reported that reduced levels of overweight and obesity were associated with demographic transition. These improvements in health status were attributed to the presence of better health education available to those living in urban areas (172).

2.3.5 Co-morbidities associated with obesity and tracking of obesity into adulthood

Overweight status during childhood may lead to both short and long term negative psychological and health consequences. From a psychological perspective children may display depressive symptoms, poor body image, low self-concept and an increased risk of developing eating disorders ((173); (174); (175)). From a health perspective, negative health consequences associated with overweight status in childhood include: insulin resistance; type II diabetes ((176); (177)); hypertension ((178); (179)); increased circulating levels of LDL cholesterol, total cholesterol and triglycerides levels (180), sleep apnoea (181); earlier onset of puberty (182); orthopaedic problems (183); and non-alcoholic steatohepatitis (184). In transition countries obese children have been found to be both iron deficient and to have a compromised response to iron fortification (185).

Children born to obese parents have a two to three times higher likelihood of becoming obese adults when compared to those born to normal weight parents. This is as a result of a combination of genetic, dietary and physical activity factors (186). Further to this, obese children are three times more likely to become obese adults, then their normal weight counterparts ((187); (188); (189); (190)). Data from four longitudinal studies in the United States were pooled and used to calculate the odds of being overweight at 35 years of age. Results of this study showed that with increasing age during childhood, there was an increased probability of an overweight child still being overweight at 35 years of age (191). Power et al. (192) agreed with this and elaborated that being obese after five years of age increases the risk of persistent obesity through into adulthood. These children and adolescents are then at an increased risk of morbidity and mortality during their adult life (193). For example, an increased risk for developing:

cardiovascular disease, stroke, hypertension, diabetes, gallbladder disease, osteoarthritis, and some cancers ((194); (195)). In fact, adults who were obese adolescents display adverse health outcomes, independent of their present adiposity (193).

2.3.6 **Methods of measurement of obesity and overweight**

The assessment of body composition in children poses some problems when compared to adults. The chemical composition of fat-free mass differs between children and adults (196). Furthermore, this composition changes during the maturation process (197). These factors each create unique challenges when assessing body composition in the paediatric population. Therefore, a critical examination of the five most commonly used methods to assess overweight status will provide insight into the most appropriate test for use in the current study.

2.3.6.1 **Densitometry**

Densitometry refers to a highly accurate laboratory based method to assess body fat (BF) percentage. The main assumption of this method is that the body is composed of two different parts, fat mass and fat-free mass. Both compartments are assumed to have constant and known densities (198). Hydrostatic weighing and dual-energy X-ray absorptiometry (DEXA) are the two main methods of densitometry (199). Hydrostatic weighing requires total submersion and full co-operation of the subject, making it a less desirable method, especially in children (199). DEXA measures the attenuation by the body of two different energy level X-rays. Software differentiates the signal and calculates bone mass, fat mass and fat-free tissue mass (200). This method is presently accepted as the gold standard and has a low radiation dose, with a relatively rapid scanning period, making it highly suitable for body composition assessments within the paediatric population ((201); (202)). Ellis et al. (202) has suggested that paediatric subjects should be age matched. This reduces variations in DEXA determinations caused by subject weight differences. However, DEXA requires expensive, non-portable equipment which makes it inconvenient and impractical for large sample groups or field studies.

2.3.6.2 **Skinfolds**

The use of skinfold measurement in estimating body fat is based on the relationship between subcutaneous fat deposits, internal fat deposits and body density (61). Skinfold assessment in children is limited for a number of reasons. There is an alteration in the subcutaneous fat pattering during maturation (197). Therefore, it is probable that the relationship between body density and skinfold thickness (and thus calculated body fat) is dependant on biological age (203). Younger children have higher water content in their adipose tissue, which leads to greater compressibility of the skinfolds (204), resulting in increased measurement error in younger children. Additionally, if a number of sites are assessed this method may become time consuming and therefore impractical for very large sample sizes.

2.3.6.3 **Bio-electrical impedance**

Bio-electrical impedance assumes that the electrical conductivity of the fat mass in the body is less than that of the fat-free mass (205). This method also assumes that the body is cylindrical, with a normally hydrated fat-free mass (206). Care should be taken when using this method as equations created to estimate body fat percentage from bio-electrical impedance are often quite specific to the population from which they were originally developed (207). Errors in the prediction of body fat percentage from this method may arise if there are differences between the subjects in the proportional length of the limbs with respect to body height (199). Additionally, when using densitometry as the gold standard, BMI was found to give a better indication of body fat percentage than bio-electrical impedance in a group of adults (199). However, the main advantage of the bio-electrical impedance method over BMI is that it is able to differentiate between fat and lean mass (207).

2.3.6.4 **Near-infrared interactance**

Near-infrared interactance (NIR) is based on the concept that different types of body tissues absorb light at different wavelengths. Body fat percentage and lean body mass are determined from prediction equations derived from the area under the curve for each spectrographic parameter (208). This method allows for rapid testing of large groups even though it has shown some inaccuracies at the extremes of measurement ((209); (210)). NIR has displayed good repeatability and low intra and inter-observer variability when using well trained readers. However, when compared with BMI, NIR does not offer much improvement in reliability, especially when the extra measures which are required are taken into account (211). The main drawback with NIR is that it has not yet been fully validated for children and adolescents.

2.3.6.5 **Body mass index (BMI) and anthropometric measurements**

BMI is a measure of weight corrected for height, defined as weight/height^2 (kg.m^{-2}) (212). Height and weight are routinely included in an individual's medical record rendering BMI a convenient measure of predicting adiposity (213). A definition of overweight status based on weight and height is also advantageous as reasonably precise measurements may be taken in a variety of field, clinical and laboratory settings (87). A high correlation between BMI and body fat percentage has been demonstrated by a number of studies, provided gender and age are considered ((52); (214); (215); (216)). The use of BMI as an indicator of body composition, although more practical for large sample sizes, has a number of inherent problems. Differences in leg length (53), body build ((217); (218); (219)) and ethnic group ((219); (220); (221); (222)) may introduce bias, particularly in individual cases. Additionally, this calculation does not distinguish between fat and muscle. Therefore, a heavily muscled individual will appear to have a higher BMI than would be expected for his or her level of fatness (207).

The most widely used cut-off points for classification of overweight (25 $kg.m^{-2}$) and obesity (30 $kg.m^{-2}$) in adults are related to health and independent of age (223). When considering the paediatric population, absolute BMI values change substantially as they become older and thus cut-off values for categorising at risk children are dependant on age ((203); (224)). However, children usually retain the same BMI percentile ranking with increases in age (55). Therefore, Cole et al. (13) proposed the introduction of age dependant cut-off points based on growth curves and the accepted definitions of overweight and obesity at 18 years of age. They used an international sample based on children from both developed and developing countries encompassing a variety of ethnic groups including data from Brazil, Great Britain, Hong Kong, the Netherlands, Singapore, and the United States of America. They created centile curves for body mass according to gender for each of these datasets using the LMS method (225). The BMI values were converted to exact z-scores using these L, M and S values. Finally, the curves from the different datasets which passed through each adult cut-point were averaged to create a smooth curve which passed through the adult cut-off point (13).

2.3.7 **Choosing an appropriate measure of overweight/obesity for field testing of South African Children**

The five methods used to assess over-nutrition discussed in the previous section each have a number of postulated advantages and disadvantages. However, when selecting an appropriate assessment tool for the Discovery Vitality Health of the Nation study, the balance between practicality, cost, accuracy and ease of comparison with international data needed to be considered. Although DEXA is considered the ‘gold standard’ when measuring body fat percentage in children (226), it is impractical for use in large field studies due to cost, time and logistical constraints. Skinfold assessment, especially in younger children, where numerous field workers are used to record measurements may lead to many inaccuracies as a result of inter-tester variability. Bio-electrical impedance requires more equipment than BMI and results may be affected by factors such as equation choice and differences in the proportional length of limbs between subjects. NIR had not been validated in children at the time of data collection. Although BMI has a number of disadvantages, ease of measurement and extremely low inter-tester variability are important advantages which should not be overlooked. The sample for this project was large (n = 10 000) and the wide range of socioeconomic conditions under which testing was conducted necessitated a testing method which would not be effected by external factors. Additionally, comparative epidemiological data from South Africa and a number of other countries was available for classifications of over-nutrition according to BMI. After weighing up all of these factors, BMI was chosen at the most appropriate measure for assessing children at risk for overweight and obesity.

2.4 **Reference Population data**

The choice to use anthropometric indicators to assess nutritional status means that an appropriate reference population needed to be selected for two reasons. Firstly, a reference population is required when making comparisons between the nutritional statuses of different populations. Secondly, a reference population is necessary when examining trends over time in a single population. An overview of the criteria for selecting appropriate reference populations and the reference populations available for selection follows.

2.4.1 **Criteria for selecting a suitable reference population**

In 1977 Waterlow et al. (227) suggested a number of criteria which should be followed when creating nutritional reference data. Firstly, the sample should be drawn from a well-nourished population, including a minimum of 200 individuals in each age and sex group. Secondly, comparison populations are usually sampled cross-sectionally for nutritional analysis and therefore reference population sampling must use a cross-sectional design. Next, the sampling methods should be fully documented and easily reproducible. Measurements should be made by well trained observers using reliable, frequently recalibrated equipment. Variables assessed should include all possible anthropometric measures required for the appraisal of nutritional status. Finally, the data and smoothing methods used in the creation of reference tables and graphs should be freely available and fully defined (227).

2.4.2 **The evolution of nutritional anthropometric reference data**

One of the first attempts to create reference values for the average height and weight of children was in 1887 and was based on data from school-aged children living in the Boston area of the United States ((228); (229)). By the beginning of the 20th century, Boas ((230); (231)) had described the general growth patterns of American children reasonably well. Over the next half decade a number of other researchers published different growth charts ((232); (233); (234); (235); (236); (237); (238)). However, these all tended to use data from homogenous groups and thus were not widely applicable (229).

During the 1960s and 1970s the most commonly used American reference was the “Harvard growth curves”, based on data from American children (239). In the United Kingdom a similar reference called the “Tanner growth curves” was in use (240). This was based on data from a group of English children (27). The WHO distributed a combined gender version of the “Harvard growth curves”, which led to the adoption of this as the international standard (30). However, there was general dissatisfaction with these norms because of their lack of large-scale applicability. This led to the release of the NCHS standards, in 1977 (7). These tables of heights and weights for different ages, derived from data collected nationally by the US National Centre for Health Statistics ((227); (241); (27)) were therefore more widely applicable. Data for children 2 years and under were derived from the Fels dataset (242).

As a response to concerns that the “Tanner growth curves” (240) were no longer able to accurately describe British children, a new set of British reference curves were developed in the early 1990s. These norms used seven data sets of which the majority were nationally representative. However, the widespread applicability of these data were compromised because only data from white children was included in their construction ((243); (224); (225).

In 1993, a WHO Expert Committee identified both biological and technical problems with the NCHS/WHO growth reference curves which made them inappropriate for assessing growth patterns of individual children and populations ((244); (7); (242)). The two main concerns with these norms were the use of two unrelated samples (the Fels and the NCHS datasets) and the inclusion of overweight and obese children in the sample which led to an upward skewness of the standard reference (242). In May 2000 the US CDC published new growth charts based on 5 nationally representative United States surveys performed between 1963 and 1994 ((97); (245)). However, although an improvement on the previous datasets, this reference still contained a number of drawbacks. For example, the infant section of the curves was based on a small sample size (245), with relatively large age gaps (246) and contained a combination of breast- and formula fed infants ((247); (35)). In response to these flaws, the WHO released revised growth curves. These were based on the same sample as the 1978 CDC/WHO norms (7), with supplementation of data from children below 6 years of age. However, modern statistical methods were used to increase the accuracy of these curves ((248); (249)). Some of the improvements included in the revised curves were a BMI-for-age reference covering a larger age range, and +1 and +2

SD BMI-for-age values which pass through the adult overweight and obesity cut-off points at age 19 respectively (35).

2.5 Choosing an appropriate reference for assessing nutritional status for field testing of South African children

Many of the early growth reference curves used local, non-representative samples and are therefore inappropriate for present day use. Over the years numerous reference curves have been offered to address problems raised with previous reference data. When evaluating which reference curves are the most appropriate for present day use comparisons between those reference curves which are most widely used today should be considered.

Table II, shows the large differences in the suggested cut-off points for boys and girls at risk of overweight and obesity observed for different age groups. These disparities highlight the need for careful choice of an appropriate reference when using nutritional anthropometry to assess the nutritional status of South African children.

The size and shape of children from different nationalities and ethnicities under five years of age are similar (51). However, school aged children and adolescents may differ between different nationalities and ethnic groups with respect to body size (43). Therefore, the 1990 British reference curves are likely to be inappropriate for use in a multi-ethnic population such as South Africa, as this reference only includes white British children. Even though the WHO 2007 curves and the CDC 2000 curves both use primary school children from the developed nation of the United States of America, the sample is multi-ethnic rendering it more suitable than the British reference.

Table II: BMI reference values for 6 – 13 year boys and girls according to three different reference definitions.

Age (years)	Level 1: Overweight [1] WHO (2007)	Level 1: Overweight [1] CDC/WHO (1978)	Level 1: Overweight [1] IOTF (2001)	Level 2: Obesity [2] WHO (2007)	Level 2: Obesity [2] CDC/WHO (1978)	Level 2: Obesity [2] IOTF (2001)
Boys						
6	16.80	16.64	17.55	18.50	18.02	19.78
7	17.00	17.37	17.92	19.00	19.18	20.63
8	17.40	18.11	18.44	19.70	20.33	21.60
9	17.90	18.85	19.10	20.50	21.47	22.77
10	18.50	19.60	19.84	21.40	22.60	24.00
11	19.20	20.35	20.55	22.50	23.73	25.10
12	19.90	21.12	21.22	23.60	24.89	26.02
13	20.80	21.93	21.91	24.80	25.93	26.84
Girls						
6	17.00	16.17	17.34	19.20	17.49	19.65
7	17.30	17.17	17.75	19.80	18.93	20.51
8	17.70	18.18	18.35	20.60	20.36	21.57
9	18.30	19.19	19.07	21.50	21.78	22.81
10	19.00	20.19	19.86	22.60	23.20	24.11
11	19.90	21.18	20.74	23.70	24.59	25.42
12	20.80	22.17	21.68	25.00	25.95	26.67
13	21.80	23.08	22.58	26.20	27.07	27.76

1 Corresponds to the +1 SD of the 2007 WHO reference (6), 85th percentile of BMI for age curve of the 1978 CDC/WHO (7), and cut-off points for overweight proposed in 2001 by the IOTF (13).

2 Corresponds to the +2 SD of the 2007 WHO reference (6), 95th percentile of BMI for age curve of the 1978 CDC/WHO (7), and cut-off points for obesity proposed in 2001 by the IOTF (13).

De Onis (246) identified the need to carefully consider whether secular trends towards overweight and obesity are evident in a reference population. When this is the case, it leads to an upward skewness resulting in the underestimation of the prevalence of over-nutrition and the overestimation of levels of under-nutrition (246). In 1995 the WHO pointed out this precise drawback with the 1978

CDC/WHO ((250);(7)) reference population. Therefore, even though the same raw data were used for the 2007 WHO reference, these data were cleaned prior to the construction of these curves to eliminate the effect of unhealthy weight-for-height values (35). In addition to this, modern statistical methods unavailable in the construction of prior references were used to increase the accuracy of these curves ((248); (249)). A second limitation of the 1977 reference was the lack of provision of curves for the evaluation of weight as a function of stature during adolescence (251). This limitation was corrected in both the 2000 CDC and 2007 WHO curves (6).

With respect to the identification of over-weight, when the 1990 Cole curves are compared with the 2007 WHO curves, the suggested cut-off points of the WHO 2007 reference (6) more closely match the cut-off points for adults at risk of overweight and obesity ((35); (224)). This also holds true when the 2007 WHO curves are compared to the 2000 CDC curves (35). Nevertheless, the most promising reference for the classification of over-nutrition was proposed by Cole et al. (13). They used an international sample consisting of children and adolescents from both developed and developing countries, structuring their normative curves such that the cut-off points for at risk of overweight and obesity passed through the adult cut-off points of 25 and 30 $kg.m^{-2}$ at 18 years of age respectively.

From the above discussion it would seem that a combination of references may be the most appropriate approach to a nutritional anthropometric assessment of South African children. The Cole et al. (13) classification system should be used to assess over-nutrition as it most closely matches a multi-ethnic nation in transition such as South Africa. With the absence of an equivalent reference for other nutritional anthropometric measures, the 2007 WHO curves should be used to assess underweight, stunting and wasting. However, as the 1978 CDC/WHO (7) USA reference values enjoyed wide usage for over 20 years, they may still need to be used for classification when assessing trends over time where raw data from previous studies are not available.

2.6 **Fitness, health and health-related fitness**

There is a lack of common consensus on the precise definitions of the terms: “fitness”, “physical activity”, “health” and “health-related fitness”, within the literature. Therefore, before continuing further it seems useful to define these terms as understood in this dissertation.

The President’s Council on Physical Fitness and Sports (252) defined physical fitness as *‘the ability to carry out daily tasks with vigour and alertness, without undue fatigue and with ample energy to enjoy leisure–time pursuits and to meet unforeseen emergencies’*. Physical fitness involves different qualities which may be either performance- or health-related. Performance-related physical fitness focuses on athletic ability and is important for performing proficiently in sport (253). It focuses on isometric strength, speed, agility, power, arm-eye co-ordination, and balance (254).

Health-related physical fitness highlights the link between physical activity and health, thereby decreasing the risk of disease and advancing health (255). The five main components of health-related physical fitness include: cardiorespiratory efficiency (sub-maximal exercise capacity, maximal aerobic power, blood pressure, lung function and heart function), a muscular component (power, isometric strength and muscular endurance), a morphological component (BMI, bone density, body composition and flexibility of the lower back and limbs), a motor component (speed, agility, balance and co-ordination) and a metabolic component (insulin sensitivity, glucose tolerance, blood pressure, substrate oxidation features, and lipid and lipoprotein metabolism) ((61); (256); (257); (254)). Most importantly, an individual’s level of performance in various categories of health-related fitness may be considerably enhanced through regular exercise and weight control (61). The lack of development of many of these components are precursors to the development of future disease within the clinical context (254). The level of physical fitness is measured through the use of tests and test batteries specific to this purpose, which are discussed later in this review.

Health refers to a combination of physical, mental, and social well-being ((61); (258)). It was traditionally associated with the negative aspects of disease, sickness and illness behaviour ((259); (260); (261)), but has now taken on a more positive connotation (262). Breslow (258) stated that health is focused on the, *'living state rather than on the categories of disease that may cause morbidity and mortality'.*

Physical activity refers to *'any bodily movement produced by skeletal muscles which results in energy expenditure'* (253). Activities of daily living classed as physical activity include: occupational, sports, conditioning exercises, household or other activities (253). There is a positive correlation between physical activity and physical fitness, with increases in the frequency, duration and intensity of movement involved in the physical-activity ((263); (61); (264)). Chronic disease patients benefit from physical activity, specifically type II diabetes mellitus ((265); (266)) and cancer patients ((267); (268)). Studies have shown that regular physical activity protects against the development of obesity ((269); (270)) and hypertension ((271); (272); (273)).

Overall, with regular physical activity there is an improved level of physical fitness. This in turn leads to a diverse range of health benefits ((274); (275)). In addition to this, physical fitness has been linked to total and cardiovascular mortality ((276); (277)), such that even small increments in physical fitness may result in lowered mortality (278). A schematic representing the interaction of these different terms is shown in Figure 4.

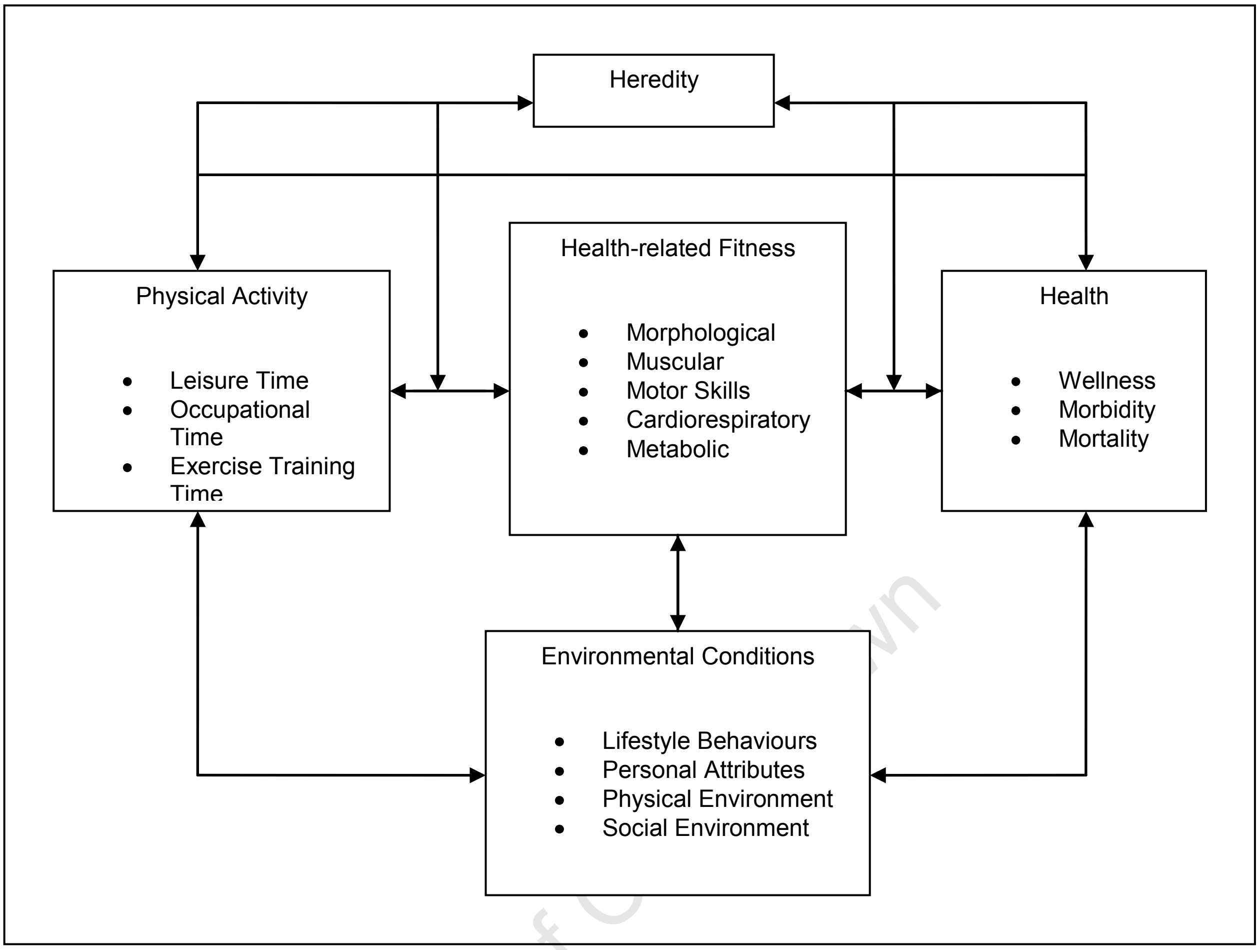

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Figure 4: Model of the relationships between physical activity, fitness and health (Adapted from (255); (254)).

2.6.1 The importance of physical activity and fitness in children

Physical activity during childhood has a number of postulated advantages. Children who are physically active tend to display healthier cardiovascular profiles, a lower body fat percentage and develop higher peak bone mass than their sedentary counterparts during childhood ((279); (280)). Opper et al. (281) has suggested that the main advantages of good physical fitness arise from its role in fortifying the cardiovascular system and improving economy of movement. These factors are manifest as a lowered metabolic risk profile, positive effects on psychosocial outcomes, a reduction in psychosomatic disorders and fewer accidents ((281); (282)). It is proposed that the causes of chronic disease and adulthood obesity often originate in childhood ((283); (284)). Linked to this is the proposal that the physical activity habits established during childhood and youth are likely to form the physical activity habits of the individual as an adult in the future ((285); (286)).

2.6.2 Tracking of activity and fitness

Based on the assumption that physical activity and fitness in childhood and adolescence is beneficial for adult health then the analysis of these connections is called tracking. Tracking may refer to two main concepts. The first is related to the stability of maintaining a relative position or rank within a sample over a time period. The second concept concerns the ability to predict the value of a given variable later in life from a measurement taken earlier in life ((287); (288); (289)). Blair et al., (290) have proposed a conceptual model which illustrates the possible relationships between physical fitness, physical activity and health during youth and adulthood. This model depicts both direct and indirect benefits of childhood exercise on adulthood health and exercise habits (Figure 5).

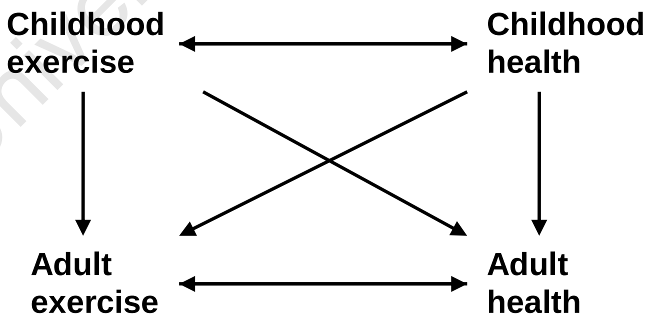

Figure 5: Conceptual model of the effects of childhood exercise habits on health throughout life (Adapted from Blair et al., 1989).

Assessing the degree of tracking of physical activity and fitness over the lifespan has been limited by: the lack of accurate instruments for physical activity assessment, the difficulty of retaining research subjects over prolonged periods of time, and the inherent variability of daily and seasonal physical activity patterns. Earlier studies tend to show a low level of tracking, but with improvements in study design and assessment techniques, more recent studies have shown higher levels of tracking (291).

Rank correlations conducted on the relationship between physical activity levels of Harvard Alumni who were athletes in college and their adult physical activity levels, showed positive but low levels of correlation over a 30 year time period (292). Tracking of VO_{2max} in adolescents showed average year to year correlations of r = 0.30 (293). Pate et al. (294) followed the physical activity, inactivity and fitness levels of children between the 5th and 7th grade. They noted intraclass correlations ranging between R = 0.78 to 0.82 for physical fitness, R = 0.63 to 0.78 for physical activity and R = 0.49 to 0.71 for inactivity. The tracking of sedentary behaviour, physical activity and physical fitness in pre- and early pubescent adolescents was considered by Janz et al. (295). They noted that correlations between activity and fitness over a five year period were moderate to high. If a boy was classified as sedentary at baseline they were 2.2 times more likely to remain sedentary when compared to their active counterparts. Higher levels of tracking of vigorous activity were noted among girls, whereas sedentary activities tracked to a larger extent among boys.

Taylor et al. (296) considered both positive and negative factors related to tracking. Skills and participation in sport during the teenage years were positively correlated with the same aspects during adulthood (r = 0.16 and 0.17, respectively). However, those who were required to exercise during their preteen and teenage years showed a negative correlation with participation in physical activity as an adult (r = -0.20; preteen vs. adult and r = -0.15; teenage vs. adult).

Beunen et al. (297) found that health- and performance-related characteristics observed during adolescence contributed equally to the level of physical activity during adulthood. This tracking was most evident in the components of flexibility, static strength and power (286).

Results from these studies suggest that the promotion of physical activity early in life may be vital with respect to long term health, as activity patterns and fitness track into adolescence and adulthood. However, children should not be required to participate against their will as this may negatively impact their future involvement (296).

2.6.3 Declining levels of physical fitness

There has been a reported decline in the physical performance of children and adolescents from Northern America, Europe and Australia over the past two decades ((298); (299); (281)). A difference in ability of approximately 10% was displayed between 1975 and the year 2000 in both boys and girls. This deterioration in physical performance was most evident in tests of flexibility and endurance in both boys and girls ((281); (298)).

Australian researchers (299) studied the changes in performance, of children and adolescents, ranging in age from 6 to 19 years, from eleven different countries (mainly developed) between 1980 and 2000. The results of the 20 meter shuttle run test, a marker of aerobic fitness, were analysed by age, gender and country. The decline in aerobic fitness was similar between males and females and largest among the older age groups. The yearly rate of decline in fitness performance differed between different countries with the USA showing the largest annual declines at approximately 2%.

Two cross-sectional studies conducted 12 years apart, assessed the performance on a maximal cycle test of 9 year old Danish children (300). These authors found that Danish boys performed significantly poorer in 1997 when compared to Danish boys in 1985. This same decline in aerobic performance was not noted among the girls. However, in both genders there was an increased difference between the ranges of aerobic fitness levels in the 1997 group when compared to the children assessed in 1985. A cross-sectional study examining 4 to 14 year old urban American children used the Bruce treadmill test to assess differences in physical fitness between 1978 and 2002. They found a significant decrease in mean endurance time over this 20 year time period such that 61% of males and 81% of females performed below the 25th percentile of the 1978 reference (301).

2.6.4 **Physical fitness in children**

The evidence indicating that physical fitness, physical activity and health track into adulthood, when viewed concurrently with the secular trend of declining fitness levels is highly concerning. There is a need to target children at a young age and create awareness of the benefits of exercise while also outlining the negative health consequences associated with low levels of physical activity. To gain an understanding of the health-related fitness characteristics of a given population group, an understanding of the components comprising health-related physical fitness is needed.

For this discussion health-related physical fitness components may be divided into functional and structural factors. Functional factors include: muscular endurance, muscular strength, balance, flexibility, power, agility, speed and resistance to fatigue. Structural factors consist of body composition and body structure. Subsequent to this discussion, the methodological approaches to measuring these fitness constructs in children will be considered in some detail.

2.6.4.1 **Muscular endurance**

Muscular endurance is the ability of a muscle or group of muscles to maintain a maximal voluntary contraction or perform a combination of concentric and eccentric contractions for an extended period of time ((254); (302); (255)).

2.6.4.2 **Muscular strength**

Muscular strength is the maximal force which may be generated by a muscle or group of muscles. It is assessed through the use of handgrip dynamometers, tensiometers and strength gauges (254). From puberty the rate of increase of absolute strength in males is faster compared to females, possibly due to the presence of increased levels of circulating testosterone in males. During late childhood and adolescence, when adjustments for difference in height are made, lower body strength is similar between the genders but upper body strength is almost twice as much in males as in females ((303); (293)).

The increase in muscle strength which accompanies training occurs regardless of age and gender ((304); (305)). For example, strength increases in both pubescents and prepubescents, following participation in a resistance training programme ((305); (306); (307); (308)). In addition, there was no difference in the degree of strength gained after training between prepubescents, pubescents and postpubescents (305).

Differences have been reported in the strength of children from differing socioeconomic backgrounds ((309); (310); (293)). These differences may become particularly evident during and after puberty (309). As muscle fibre size is a major predictor of muscle strength, differences have traditionally been attributed to variations in the growth of muscle mass ((310); (293)). However, Henneberg et al. (309) attributed differences in specific grip strength to differences observed in the speed of neuromuscular reactions between children from the different socioeconomic classes (309).

2.6.4.3 **Power/explosive strength**

Muscle power is the ability to perform a maximal, dynamic contraction of one or more muscles and is measured as the maximum work rate of the muscle or group of muscles assessed (254). Power is a product of force and velocity. The force required to produce power depends on strength (311). Indeed, the power of a subject is directly related to their strength, implying that stronger individuals would score higher on tests of power than their weaker counterparts (312).

2.6.4.4 **Agility**

Cureton and Kasch (313) defined agility as, *'the capacity for fast reaction in controlled movement where "accuracy" is also a feature'.* Agility is also dependant on possessing the ability to change direction accurately and quickly while moving rapidly (314).

2.6.4.5 **Speed**

Speed is defined as the ability to move a part or the whole of the body as fast as possible over a given distance ((254); (262)). Speed is dependent on co-ordinated neuro-muscular capacity for rapid limb movement, agility, strength, coordination and short-term muscular endurance (315).

Speed is influenced by muscle fibre type. Fast-twitch muscle fibres have a fast rate of contraction and a high capacity to generate ATP anaerobically. Slow-twitch fibres have a slower rate of contraction and are able to sustain continued muscular contractions as a result of their ability to produce ATP aerobically. The distribution of the fast and slow twitch fibres within a muscle varies considerably between people. The percentage of fast twitch and slow twitch fibres has genetic origins (61). The manifestation of speed also depends on reaction time which can be influenced by psychological and physiological factors (262). If an untrained individual increases strength the relative velocity of muscular contraction at each level of strength will be higher, leading to a more economical use of energy, resulting in improved speed (312).

Initially, it was assumed that tendon reflexes and simple motor patterns, such as those assessed in tests of speed, were similar among children of similar age (316). However, Wolff et al. ((317); (318)) showed age-specific variability of motor performance in children which in turn can contribute to variations in speed. Differences in speed have been noted between the genders with males having a slightly superior performance to females. However, as speed is influenced by strength, these differences may actually result from the differences noted in strength between the genders (319).

2.6.4.6 **Flexibility**

Flexibility is the range of motion that occurs in a joint or group of joints (320). Flexibility may be defined as either static or dynamic. Static flexibility gives an indication of the mobility of a joint without considering the speed of movement. Dynamic flexibility includes a measure of the speed at which peak joint mobility is gained (321). Joint flexibility is restricted by three main factors: 1) the periarticular connective tissues including: tendon, ligament, bone, and joint capsule 2) the muscle and its fascial sheath 3) the skin ((322); (323)).

When flexibility is assessed as part of a general battery of tests, static flexibility is usually assessed, due to the difficulty and risk of injury during tests of dynamic flexibility (323). Flexibility has a high degree of specificity dependant on the joint tested and therefore caution should be taken when inferring the flexibility results of one joint to that of the body as a whole (324).

Flexibility is important for health-related fitness, as moderate levels of flexibility aid in the maintenance of balanced bodily alignment (324). Improvements in flexibility resulting from regular stretching have been shown to improve physical fitness performance in seven studies ((325); (326), (327); (328); (329); (330); (331)). More specifically, improvements were noted in maximal voluntary contraction, contraction velocity, concentric and eccentric contraction force, countermovement jump height and the 50-yard dash ((332); (325); (326); (327); (328); (329); (330); (331).

Girls tend to be more flexible than boys with differences becoming evident from approximately five years of age (333). Clarke (334) stated that flexibility decreases with age from 12 years in girls and 10 years in boys, while Hupprich and Sigersth (335) suggest that flexibility increases until adolescence and then tapers or levels off during adulthood. However, significant decreases in flexibility have been noted between kindergarten and second grade children (336).

2.6.4.7 **Resistance to fatigue**

Resistance to fatigue has traditionally been synonymous with cardiorespiratory endurance, and is also referred to as aerobic fitness (61). This variable has been measured through the assessment of maximal oxygen consumption via VO_{2max} tests or through sub-maximal tests, which estimate the VO_{2max} value. The ACSM (302) has defined cardiorespiratory endurance as the ability to perform dynamic, large muscle movements at a moderate to high intensity, over a prolonged period of time. The most common field test protocols designed to measure maximal oxygen uptake include both step (337) and running tests ((262); (338)).

During childhood boys and girls have similar VO_{2max} values. However, differences in maximal oxygen consumption become evident between the genders at 12 to 13 years of age (339). Additionally, it has been hypothesised that the rate of development, genetic endowment, body composition and habitual levels of physical activity, influence endurance performance in the paediatric population (340).

There are a number of factors which suggest that VO_{2max} should not be considered as a marker of potential endurance performance ability in prepubertal children ((341); (342)) For example; children display inferior ventilatory efficiency, lower blood oxygen carrying capacity and a possible impairment in cardiac output and stroke volume. These factors improve with growth. Massicotte et al. (343) reviewed several studies comparing distance-run and VO_{2max} performances in children and found a moderate correlation (between r = 0.6 and 0.7) between the two variables. VO_{2max} values, when assessed relative to weight, tend to decrease or stabilise with increases in age. However, endurance performance improves with age (344). Additionally VO_{2max} differences between children are influenced by factors other than cardiovascular function, especially body composition (342).

2.6.4.8 **Body composition**

Body composition is represented by fat mass and lean mass (muscle, bone, vital tissue and organs). As discussed earlier body composition may be assessed through a number of methods including: DEXA, anthropometry, ultrasound, radiographs and hydrostatic weighing (61) (Section 2.3.6). An optimal ratio of fat to lean body mass is associated with health-related fitness.

2.6.4.9 **Body Structure**

The variables of body structure most commonly measured in health related fitness tests of the paediatric population include height and mass. These two values are often used to calculate BMI, a measure of the “normalcy” of an individual’s body weight (61). Growth curves have been developed which are used to determine normal growth patterns for height, mass and BMI for given ages, according to a healthy reference population. This has been discussed earlier (Section 2.4).

2.6.5 Differences between boys and girls related to physical fitness

The physical performance characteristics are generally similar between boys and girls aged five through eleven years. Although a slight superiority of performance may be observed in boys, there are no overall significant differences. From approximately eleven years of age girls begin adolescence. At this stage, girls overtake boys in characteristics which were previously indistinguishable, and close the gap in areas which they were previously inferior. After about two to two-and-a-half years, boys experience their growth spurt and reassert their superiority of performance (345). At about thirteen years of age the performance of girls on many motor tests plateaus and may even start to decrease again with age. Among boys, there are continued improvements in skills involving strength, power and muscular endurance into and during adolescence (333).

2.7 Fitness testing within the paediatric population

Children should be considered a special population and thus the same approach used to test the physical fitness levels of adults may not be appropriate in children. A variety of tests and test batteries have been used to gain an indication of the physical fitness level of children, however there is no test battery that is used primarily, to the exclusion of others.

Within the past thirty years, the focus on tests of motor performance and athletic fitness has decreased. Instead, the emphasis has increasingly been placed on measures which assess aspects of good health and disease prevention, referred to as health-related fitness (255).

2.7.1 **Cross sectional vs. Longitudinal Methods**

Studies of the paediatric population which assess the skills of different age groups during the developmental period may either follow a cross-sectional or longitudinal approach. Cross-sectional studies take measurements at one time point from a group of children across the full age range being assessed. Children are classified according to age and gender and results include norm-referenced data useful for assessing the fitness related measures of children. Longitudinal studies take multiple measurements at set time points, over a much longer period of time, following a single group of children as they age (346).

Historically, the majority of studies have used a cross-sectional approach as longitudinal studies have some inherent challenges. Environmental factors are difficult to control over time and invariably there are a number of dropouts from the study, which may distort the nature of the sample. Decisions on the frequency at which measurements should be conducted may be problematic as a result of the need to balance cost of testing versus acquiring a sufficient range of data to facilitate meaningful research outcomes. Longitudinal studies are also more costly (346).

2.7.2 **Which tests of physical fitness should test batteries include**

Tests of health–related physical fitness should follow certain criteria. For instance, they should assess the entire range of function, from extremely limited to a high level of functionality. It is also important that a person's score on a given test item is able to improve with suitable amounts of physical activity (61).

Reliability and validity are factors used to evaluate the usefulness of a given fitness test (262). Reliability refers to the ability of the test to give the same score when repeat testing is conducted. Validity is an assessment of whether a test actually measures the component which it claims to measure. In the area of physical fitness it may not always be possible to determine a precise value against which to assess tests. In this situation, a criterion test (one accepted as the best available for the given component) is used as the benchmark against which other tests are evaluated (262). An example of a criterion test is the use of maximum oxygen consumption measured on a treadmill to assess the validity of using timed or distance runs as an estimate of cardiorespiratory fitness (347).

2.7.3 Guidelines for health related fitness testing in children

The most common components included in paediatric test batteries and surveys are: muscular endurance and strength, flexibility, resistance to fatigue, and structural factors (See Table III). Power and speed are assessed to a lesser degree. When testing large groups of children it is most practical to use tests which allow for simultaneous testing. Additionally, practicality necessitates the use of tests which require inexpensive equipment and utilize the least amount of space to conduct.

2.7.3.1 Muscular endurance and muscular strength

The most commonly used tests to assess muscular strength and endurance are: timed curl-ups and sit-ups, push-ups, pull-ups, and the bent arm hang ((254); (348)). The sit-up test measures abdominal endurance, whereas pull-ups indicate upper body muscular endurance. The sit-up test is easily administered and requires minimal equipment. Numerous assessments in primary school children, conducted between 1957 and 1997, have shown test-retest correlation coefficients ranging between $r = 0.62$ and 0.94 ((349); (350); (351); (352); (353)). Ball (354) showed correlation coefficients of $r = 0.57$ when compared to the 1-RM trunk flexion score (measure of muscular strength) and $r = 0.4$ when compared to a 60% 1-RM (measure of muscular endurance). The modified pull-up, the free hanging pull up, the flexed arm hang, and the 90° push-up have been proposed as tests of the upper body to be used in the assessment of muscular endurance. Although, these tests each have specific anatomical logical validity, they are not anatomically interchangeable (355). The validity coefficients of these tests when compared to criterion tests of similar musculature only account for between 16 and 32% of the variance. Additionally, these tests are difficult to administer as they require more equipment than the sit-up test and the individuals cannot be tested concurrently.

When assessing children there are many zero and low scores recorded on the pull-up test (356). Therefore, the modified pull-up test usually replaces this test in the paediatric population (357). However, Erbaugh (358) showed that the modified pull-up was unreliable (r = 0.52) and time-consuming when testing large groups as the equipment must be adjusted for each different student. Considering these limitations, the sit-up test is the most practical test to measure muscular endurance in a large group of children.

2.7.3.2 **Power/explosive strength**

Tests of muscle power and explosive strength usually involve a single effort and may include the vertical jump (359) or standing long jump (360). Although the whole body mass is moved during these tests, they mainly assess the power of the lower limbs. Both of these tests have proved valid (r = 0.78 and 0.61) and reliable (r = 0.93 and 0.96) tests of power, respectively (262). Although not all test batteries include a test of power, the most common test is the standing long jump (Table III).

2.7.3.3 **Agility**

The most common tests of agility are the shuttle run (360), quadrant jump and the side-step test (361). Of these, the side-step test has a high level of reliability (r =

0.89) and acceptable face validity (361). However, these tests only assess the agility of the lower body (262). Lamb (262) points out that test performance on these tests may be affected by the surface on which the test is conducted and the footwear worn by the subject.

2.7.3.4 **Speed**

Speed is only assessed in four of the most common test batteries (Table III). In tests of speed, face validity is accepted, as a person's speed determines how fast they will run (262). However, Levin and Gutin (362) point out that speed may be affected by physical exertion, possibly explaining the low rate of inclusion in test batteries.

2.7.3.5 **Flexibility**

The two most common tests for measuring flexibility among children include the sit-and-reach (363) and the trunk-lift test (364). The trunk-lift test showed reliability of r = 0.93 to 0.98 and validity of 0.68 to 0.70, when correlated with goniometer scores (364). However, if flexibility of a single joint is measured it cannot be assumed that this measurement represents the whole body ((365); (366)). The sit-and-reach test does not focus on a single joint but rather measures hip, knee, and trunk flexion (323) and is highly reliable with reported test-retest correlation coefficients as high as 0.99 (367). The validity of the sit-and-reach test is usually assessed through a combination of two criterion tests, one which assesses hamstring flexibility and the other which measures lower back flexibility. Jackson and Baker (367), showed correlation coefficients of r = 0.64 when compared to the straight leg raise (hamstring flexibility) and r = 0.28 when compared to the modified Schober test (lower back flexibility). It is also the most commonly used test of flexibility among children (Table III).

2.7.3.6 **Resistance to fatigue**

There is debate about the reliability of distance run tests in young children as these tests induce fatigue and require a high degree of motivation. Safrit et al., (368) reviewed the reliability of distance run tests in the youth. They reported reliability coefficients ranging between r = 0.60 to r = 0.90 for the 600 yd, 1600 m, 9 minute, and 12 minute runs. Research in a group of preschool to fourth grade children, has shown that one mile (1600 m) run/walk time is reliable from grade two onwards. The half mile (800 m) distance proved to be the only reliable distance run test in the first grade and preschool children (369). Krahenbuhl et al. (370) tested grade 1 to 3 children using the 800 m, 1200 m and 1600 m tests. Following instruction and practice in paced distance running, the 1600 m distance was the most reliable test across all of the groups tested.

Rowland et al. (371) established that maximal oxygen consumption and body fat content, contributed equally to one mile run performance in preadolescent boys. These two factors together accounted for 60% of the variance in test performance. This brings into question the accuracy of one mile run performance as a strong measure of cardiovascular endurance in children. Yoshida et al. (372) displayed a correlation between the endurance performance of a group of 6 year old children and their VO_{2max} values ($p < 0.01$). However, this relationship was not as strong as that generally observed in the adult population.

A large problem when attempting to gain a measure of resistance to fatigue in children is their level of motivation. Yoshida et al. (372) used a subject group of 6 year old children and assessed three different endurance performances (1500 m, 4000m and 8850 m). The child performing the best maintained a constant heart rate. However, the child who gave the poorest performance displayed a decrease in heart rate. It is probable that this occurred as a result of decreased levels of motivation.

Lack of knowledge of pacing strategies in children can be a confounding factor in achieving an accurate indication of endurance ability. This is of particular importance in maximal distance tests. Those children who start the test at a pace that is too fast will tire and drop out before those who start the test at a slower pace. Additionally, those children starting at a slower pace will be able to run for a longer distance than those who started the test at a much faster pace (373). Saltarelli and Andres (374) showed that the practice of steady pacing resulted in an improved running test performance in children.

These factors, along with the wide variety of tests used to assess this fitness component (see Table III) all indicate the lack of consensus which exists in the current literature on the most suitable test. Factors such as motivation, especially when testing younger children, should be considered when choosing the most appropriate test for measuring resistance to fatigue.

2.7.3.7 **Body composition**

The assessment of body composition in children poses some problems when compared to adults. The chemical composition of fat-free mass differs between children and adults (196). Furthermore, this composition changes during the maturation process (197). This complicates the choice of the most appropriate field test to assess body composition in the paediatric population. An overview of currently used tests and the choice of an appropriate measure of body composition have been discussed earlier (Section 2.3.6 - 2.3.7).

2.7.3.8 **Body Structure**

It has been postulated that groupings within the paediatric population, made on the basis of chronological age are not the most appropriate means of classification. In preadolescent children, Katzmarzyk et al. (375) has shown that a combination of skeletal maturity and chronological age was the strongest predictor of motor performance, whereas body mass was the best predictor of strength. As absolute strength increases proportionally with body height in children, early maturers may be expected to perform better on strength tests than late maturers (376).

Research has shown that differences in motor performance are small up to 13 years of age but become quite marked in 14 to 18 year olds boys (293). These differences are not evident to the same degree between the genders. Variability in motor performance between young females during maturation seems to be accounted for almost exclusively by differences in height and body mass whereas young males display some qualitative differences in performance as a result of different stages of sexual maturity. These results seem to stress the need to take into account biological maturity when assessing physical activity in boys, especially after 13 years of age (377). However, a study of 9 to 19 year old Swiss children (378), reported that in the majority of tests from the 'Eurofit test Battery', chronological age played at least an equivalent role, though was often a stronger predictor of performance than pubertal age. They did note that height and weight affected test performance independently.

2.7.3.9 Other factors affecting performance on physical fitness tests

The fitness test procedure is but one of the many factors which affect the outcome score of a fitness test. During childhood, the level of maturation and hereditary factors play a larger role on physical fitness than activity levels ((379); (380)). With an increase in age the importance of these factors decreases (381).

It has been shown ((382); (380)) that active children will still perform poorly if they are younger than the other children in their class, they are late maturers or do not have the genetic predisposition to score well on the given fitness test. Conversely, a child who is inactive but is more mature, older or has a strong genetic predisposition for a test will score higher than many of the other children tested.

Environmental factors, lifestyle factors, and motivation have been shown to have an effect on test scores (381). The presence or absence of an audience, known as social facilitation, may lead to differences in performance (262). Other factors may include: differing attitudes of the subjects to the test or tester; the skills, manner, gender and knowledge of the tester; previous experience of the given test by the subject; and whether feedback is given during repeat testing, especially if there has been an improvement in performance ((383); (262)).

The level of fatigue experienced by the subject at the time of testing also affects performance. Bezak (384) found some performance decline if a subject thought about technique while not in a state of fatigue. However, the opposite was noted if the subject was fatigued. The cost-benefit ratio also plays a role, particularly if the test is painful or invasive (262).

Motivation, defined as *'those psychological processes that cause the arousal, direction, and persistence of voluntary actions that are goal directed'* (385), may play an important role in athletic performance outcomes (386). The main aspects influencing motivation levels are: factors intrinsic to the athlete, consequences of performance, the level of competition and the dimensions of the given task (386). Kounovsky (387) reported that physical weakness often develops as a consequence of mental attitudes and emotions. While Witting (388) showed that high physical self-efficacy was associated with lower sport competition anxiety and better sports performance.

It is impossible to exclude or fully control for all of these variables. However, Lamb et al. (262) stress the importance of attempting to minimise these affects to as great a degree as possible, especially if comparisons will be made with previously published results (262).

Table III: The components of a number of Physical fitness test batteries used in surveys

	FUNCTIONAL						STRUCTURAL	
SURVEY OR TEST BATTERY	**RESISTANCE TO FATIGUE**	**MUSCULAR ENDURANCE**	**MUSCULAR STRENGTH**	**FLEXIBILITY**	**POWER**	**SPEED**	**BODY STRUCTURE**	**BODY COMPOSITION**
AAHPERD health related physical fitness test (389)	9-min run; 12 minute run	Sit-ups		Sit-and-Reach	Standing long jump			Skinfolds
EUROFIT physical fitness testing battery ((390); (391))	10 x 5-m shuttle run; 6-minute run; PWC_{170}	Sit-ups	Bent arm hang; Grip strength; Arm pull	Sit-and-Reach	Standing long jump		Height; Body mass	Skinfolds; Body fat
International Physical Fitness Test (392)	1-km run	Flexed-arm hang	Back throw; Grip strength		Back throw ; 10-m shuttle-run; Standing long jump	50-metre dash	Height; Body mass	Skinfolds
Prudential FITNESSGRAM (393)	20-m shuttle run (multistage); 1-mile run/walk	Curl-ups; Flexed arm hang; Modified Pull-ups; Pull–ups; 90-degree push-ups	Back throw; Grip strength; Trunk Lift Test	Back-saver Sit-and-reach; Shoulder Stretch			Height, Body mass	Skinfolds; BMI
Chrysler/AAU Fitness Test (394)	0.25- to 1-mile run	Bent-knee sit-ups; Pull-up; Flexed arm hang		Sit-and-Reach				

President's Challenge Physical Fitness Test (395)	1-mile run/walk; Shuttle run	Curl-ups; Pull-ups; Flexed arm hang		V sit reach; Sit-and-Reach				
YMCA Youth Fitness Tests (396)	1-mile run	Curl-ups; Modified pull-ups		Sit-and-Reach			Height; Body mass	Skinfolds
National Youth Physical Fitness Test (394)	300-yd shuttle run	Sit-ups; Push-ups; Modified push-ups; Pull-ups; Modified pull-ups			Standing long jump			
Fitness of New Zealand school children survey (397)	12 minute run; Canadian home fitness test	Sit-ups		Sit-and-Reach			Height; Body mass	Skinfolds
National fitness, health and physical performance survey of South Australian school children (398)	PWC_{170}	Sit-ups, Push-ups	Grip strength	Sit-and-Reach	Standing long jump	Running speed	Height; Body mass	Skinfolds
Physical Fitness of Belfast school children (399)	PWC_{170}	Sit-ups	Bent arm hang	Sit-and-Reach	Standing long jump	Running speed	Height; Body mass	Skinfolds
A joint study of physical fitness in relation to school children (400)	12 minute run	Sit-ups; Push-ups	Bent arm hang; Pull-ups; Burpees	Sit-and-Reach	Standing long jump	Running speed	Height; Body mass	

2.7.4 **The choice of an appropriate test battery**

Children tend to be generalists with respect to physical fitness. Bar-Or (344) refers to children as being *'physiological non-specialists'*, such that a child who is a good sprinter is also often a good distance runner. From this it is deduced that the inclusion of an exhaustive number of tests within a test battery is not necessary to gain a general impression of a child's health-related fitness.

Cauderay et al. (378) noted that chronological age played a large role in predicting the performance on the majority of tests used in the 'Eurofit test battery'. As chronological age is a useful classifier in school age children this played a role in our choice of test battery. This battery also required minimal equipment and many of the same tests were repeated in a number of the other test batteries and surveys examined. Therefore, the Eurofit test battery was chosen as the foundation on which the testing of a group of South African primary school children would be based. As not all of the components were appropriate for field testing in schools lacking basic infrastructure some tests were omitted, such as the bent arm hang and the PWC_{170}. Varied levels of success were mentioned in the literature when assessing resistance to fatigue, especially in young children. When considered in conjunction with the generalist fitness performance of children, a specific test of this component was excluded from the test battery used in this study. The shuttle run was however included and acted as a proxy for resistance to fatigue especially in the younger age groups.

With a specific interest to make the test battery more appropriate for the South African setting, a cricket ball throw for distance was added to determine upper body strength and power. The choice of an appropriate assessment of body composition and the choice of a suitable reference population for structural comparisons have been discussed earlier (sections 2.3.7 and 2.5 respectively).

Therefore, the final test battery chosen for use in this dissertation included height and weight as the anthropometric descriptors for each child. BMI was calculated from these values and was then used as an indicator of nutritional status.

Measures of physical fitness included the sit-and-reach test (flexibility), the standing long jump (lower body power), the number of sit-ups completed in one minute (abdominal muscular endurance), the 10 times 5-m shuttle run (speed and agility) and the cricket ball throw for distance (upper body power). The modified Eurofit test battery used in this study is described later in greater detail in the methodology chapter of this dissertation (see CHAPTER 3).

2.8 **Interactions between physical fitness and nutritional status**

Obese children are inclined to be less physically active than non-obese children ((401); (402)). The reason for this is that obese children are rarely able to perform physical activities at the same level as normal weight children, as they are required to perform any given task at a higher percentage of their maximal oxygen uptake than their leaner counterparts (344). This leads to a lower reserve capacity and hence they will experience a higher level of perceived exertion during an exercise task (403).

Kim et al. (404) identified a cross-sectional inverse relationship between physical fitness and overweight among American children and Tokmakidis et al. (405) showed that higher Body Mass Index (BMI) values in children were positively correlated with inferior fitness test scores, except flexibility. When considering only prepubescent girls, adiposity was a significant predictor in fitness tests affected by body mass but was not related to tests assessing flexibility, muscular strength, balance and speed of limb movement (406). Similar findings were noted for a group of Spanish boys and girls with respect to the adiposity being related to fitness tests affected by body mass. However, overweight Spanish children displayed greater grip strength than their normal-weight counterparts (407). The superiority in handgrip strength of obese children when compared to non-obese children was also found in a group of Flemish children (408). As muscle mass is increased by the overload principal (61), it is possible that the excess weight carried by overweight children may positively influence their strength.

In a group of Greek children, obese and overweight children scored poorer on the long jump, speed and shuttle run tests in comparison to children of normal BMI. They also tended to adopt unhealthy eating behaviours and sedentary lifestyle habits to a greater degree (409). Overweight Mozambiquean children were outperformed by their counterparts who were either normal-weight, stunted or wasted, on a full battery of physical fitness tests, with the exception of handgrip strength (410).

Body composition in undernourished groups has been shown to affect fitness performance though not necessarily with the expected directionality. Monyeki et al. (20) noted that the South African children in their sample with a higher BMI, performed better in tests of sprinting and jumping than those children with a lower BMI. In western countries a higher BMI is an indicator of over-nourishment ((411); (412); (413); (414); (415)) whereas in under-nourished children a higher BMI may be an indicator of a higher muscle mass ((413); (415); (416)).

Prista et al. (410) showed that under-nourished children generally performed better on tests of fitness than overweight children. In fact, the only test on which the overweight group performed significantly better than the under-nourished groups was the test of grip strength.

2.9 Ethnic differences

There are two schools of thought with respect to the use of classification systems based on race and ethnicity. Physical anthropologists and social scientists support the view that race and ethnicity are primarily historical and cultural constructs and as such have minimal biological significance (231). On the other hand, the treatment of racial and ethnic categories as biological taxonomies by early population geneticists disseminated the view that scientific analysis may be used to specify the nature of supposed differences between these groups ((417); (418)). Kaufman and Cooper (419) have pointed out that although the biologically simplistic views championed by the eugenics movement are no longer overtly supported, there is still a subtle presumption that racial and ethnic distinctions exist. Indeed, the sequencing of the human genome has resulted in renewed interest in racial and ethnic differences (420), with the investigation of genetic determinants of disease susceptibility (421), drug metabolism (422) and responses to the environment (423).

Historically, tests of motor performance comparing the results of black and white children from the USA have generally concluded that in early life black children show slightly superior performance on motor tasks than their white counterparts ((424); (425); (426)). This observation was continued into childhood, although the precise reasons for these disparities were not immediately apparent (346). As differences were most prominent in weight bearing activities, it may be related to differences in the amount of adipose tissue between the ethnic groups. Malina (427) noted that skinfold thickness in white, 6 to 13 year old boys and girls were on average greater than in black children of the same age. Running, jumping and throwing ability of Spanish-American boys was superior to that of Anglo-American boys, although height and weight showed no considerable differences ((428); (428); (429)). No significant differences were found between black and white American children with respect to speed of reaction time (430). A comparison of the results of a 100-yard run, 600-yard run and shot-put throw of five different ethnic groups within South Africa (White, Black, Coloured, Indian and Chinese), showed small ethnic differences. Black children gave the best performance, followed respectively by White, Coloured, Indian, and Chinese children. Pubertal loss of efficiency followed this same pattern, occurring in Indian and Chinese children first and black and white children last (431).

More recently studies seem to point towards a reversal in these trends. In two studies, African American children and adolescents displayed poorer cardiovascular fitness than Caucasians ((432); (433)). A recent study of 12 to 13 year old children residing in the greater metropolitan region of Johannesburg South Africa showed that the health-related fitness of white boys was generally superior to that of black boys. However, few significant differences were noted between the test performances of black and white girls (434). In terms of physical activity, McVeigh et al. (435) showed differences between the behaviours of black and white urban South African children from the same area. They found that black children were less active, less likely to participate in school based physical education classes and watched more television than white children.

While significant differences have been noted between the activity and physical fitness levels of different ethnic groups in a number of studies ((436); (437); (432); (433)), Lindquest et al. (438) point out that social class may be an important confounder. They propose that the majority of the statistical influence of ethnicity on physical activity and fitness may often be attributed to the disproportionate numbers of specific racial and ethnic groups within the lower socioeconomic strata. This may be especially important in South Africa, a country with a history of legislated racism. Ncayiyana (439) highlights the need to consider the long term effects of material deprivation and inequalities in health care experienced by marginalised groups. In this case, comparisons should clearly consider the root causes of differences without confusing social and economic variables with genetic determinants (440).

2.10 Socioeconomic differences

Within developed countries, children with a high socioeconomic status tend to be more active and physically fit than those children with a low socioeconomic status ((441); (442); (443); (444), (445); (446)). In contrast to this, it has been stated that in developing countries children with a low socioeconomic status tend to be more active than those from high socioeconomic status due to greater demands placed on them with respect to active commuting ((447); (448)). South Africa is a country presently in transition and as such may be expected to display characteristics falling between either extreme, depending on the demographics of the group sampled. A study conducted on urban children in the greater Johannesburg metropolitan area showed physical activity characteristics more closely related to those children of developed nations. The children with the highest socioeconomic status displayed high levels of physical activity, watched less television, weighed more and had a higher amount of lean tissue than similarly aged children with a lower socioeconomic status (435). These authors point out that prior to their study the levels of physical activity among young South Africans had not been monitored. Therefore, it is not possible to interpret these data in the context of secular trends or to assess whether similar patterns are evident among rural South African children.

Poor social conditions have been associated with a delay in maturational and functional growth curves. Matsudo (449), noted that undernourished children tended to show late maturation. A two year physical growth delay in 11 year old prepubescent Bolivian boys (450) and girls (451) of low socioeconomic status was observed when compared to Bolivian children of higher socioeconomic status. Freitas et al. (452) showed that Portuguese children with a high socioeconomic status were taller, heavier and fatter than children with a medium to low socioeconomic background. On the other hand, a cross-sectional survey of young people in England concluded that despite differences in overweight and obesity levels between gender and ethnic grouping, no differences existed between different socioeconomic groups (453). In South Africa differences were shown between the growth patterns of black children and black adolescents. High socioeconomic status, urban youth were consistently, but not significantly, larger than 'average' socioeconomic status urban and all rural youth. 'Average' socioeconomic status, urban youth consistently weighted less, and in some cases significantly less than the rural groups (454).

Significant associations between socioeconomic status and physical fitness have been noted. The Madeira growth study (455) identified that boys from high socioeconomic groups had lower scores for the sit-and-reach flexibility test and the standing long jump tests then boys from low socioeconomic groups. However, this pattern was reversed for the sit-up and shuttle run tests. Differences were considerably less marked between girls. However, girls with a high socioeconomic status performed better on the shuttle run, standing long jump and sit-up tests than girls with a lower socioeconomic status. A similar study of African children (456) showed that children from higher income groups also performed well on sit-up and shuttle run tests and poorly on sit-and-reach. Yet, with respect to the standing long jump, the boys from the high socioeconomic group performed the best. Within the Polish paediatric population, both somatic and fitness variables were poorer the lower the socioeconomic status (457).

2.11 Conclusions

From this examination of the literature it is evident that as we are living in a state of transition in South Africa, we should be concerned with both over-nutrition and under-nutrition. As aspects of nutritional status, physical activity and physical fitness have been shown to track into adulthood, it is vital that these issues are addressed at a young age. However, the inequalities of the past have left a heritage in which the lines between ethnic and socioeconomic differences have become blurred. This dissertation considers the impact which this has had on the health-related fitness of young South Africans.

CHAPTER 3

METHODOLOGY

3.1 Introduction

The "Discovery Vitality Health of the Nation Study" originated as a study of the physical fitness of children in the Western Cape Province of South Africa. Therefore, this chapter starts by providing a history of the development of the project. As one testing session was used to record all the variables for each child, a detailed description of how these variables were assessed and measured follows. The balance of the chapter has then been divided into four parts which form the framework to address the main aims of the thesis, as outlined in the first chapter of this dissertation.

The anthropometric data and the nutritional status of the children in the sample are considered in Part one (3.8.1). This section aims to describe these factors according to gender, age and ethnic group. The prevalence rates of different measures of nutritional status are also considered and grouped according to the same variables. In addition to this, a demographic adjustment is used to create national prevalence rates which may be used to examine secular trends among South African primary school children.

Part two (3.8.2) describes the analysis of the physical fitness tests used in this dissertation. These fitness tests are based on a subset of the tests included in the widely used Eurofit test battery (391). However, the cricket ball throw for distance has been added to this battery as a test of upper limb power. These data are reported according to gender, age and ethnicity.

Part three (3.8.3) details the interactions between nutritional status and physical fitness. The main purpose of this study is to determine whether differences in nutritional status effect physical fitness test performance. The possibility of a link between stunting and overweight is also considered.

Part four (3.8.4) aims to address the question of whether the social inequalities of the past have had an effect on the present anthropometric and physical fitness measures of South African children. Sampling conducted across the socioeconomic strata indicated vastly different percentage representations of each ethnic group in the different socioeconomic categories. As such, comparisons are only made between black and mixed ancestry children in the highest and lowest socioeconomic groups. White children are only examined from the highest socioeconomic group. These children are then compared to the children from the other ethnic groups in the highest socioeconomic group to examine whether the ethnic disparities documented in part one and two of this thesis are reduced when children are compared to the same socioeconomic group.

3.2 **History of the Project**

The Discovery Vitality Health of the Nation project was an extension of the “Flipfile Health of the Nation” study administered by “Sporting Chance” (Sports Science Institute of South Africa, Newlands) and sponsored by Flipfile (FlipFile, South Africa). In the original “Flipfile Health of the Nation” project schools within the Western Cape Province were identified as possible subject groups and each headmaster was sent a letter which explained the project and invited them to participate. If the schools did not respond to this letter they were followed up telephonically. The schools that responded favourably incorporated the physical fitness testing into their physical education curriculum. If children did not want to take part they were excused from participating in the testing. Very few children refused to participate in testing and therefore it is extremely unlikely that selective participation lad to a bias in study results. This phase of the project included the testing of 4 253 children.

In 2004 the decision was taken to convert the regional Western Cape “Flipfile Health of the Nation” project into a national project funded by Discovery Vitality (Discovery Health, 16 Fredman Drive, Sandton, 2146). During this second phase of testing, 6355 children were tested from the Eastern Cape, Gauteng, Free State and KwaZulu Natal Provinces of South Africa. A diagram displaying the number of children tested in each year of the project is provided in Figure 6.

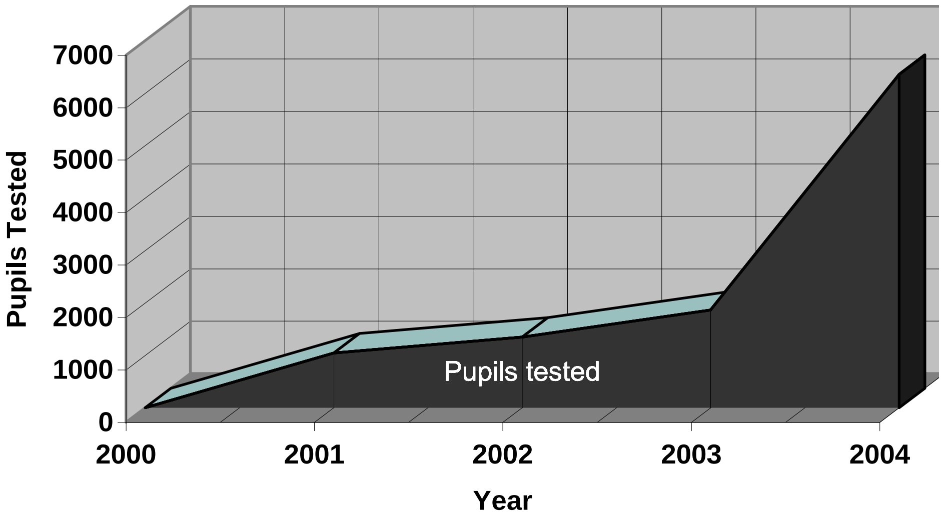

Figure 6: Duration and progress of the testing phase of the "Discovery Vitality Health of the Nation Project"

3.3 Study design

Between 2001 and 2004, anthropometric, demographic and physical fitness characteristics of 10 608 South African primary school children, from diverse socioeconomic backgrounds were assessed as part of the Discovery Vitality Health of the Nation Survey. Of this group, 10 301 children (5 615 boys and 4 686 girls) were between the ages of 6 and 13 years and were therefore considered in the analysis for this thesis. The gender imbalance may be attributed to the random selection process. This survey used a modified version of the EUROFIT test battery to assess basic anthropometry and physical fitness (391). Anthropometric measures comprised height, weight and body mass index (BMI). Fitness tests included: sit-and-reach, standing long jump, shuttle run, sit-ups and cricket ball throw. Subjects were chosen from randomly selected schools of varied socioeconomic status in different South African Provinces.

3.4 Selection of schools and subjects

A minimum of five schools from different socioeconomic strata in each of five South African Provinces was sampled. Although different testing teams were used in each province, strict quality controls were maintained during the study by using the same trained observers, calibrated scales and standardized testing methods. Additionally, each Provincial testing team was trained by the same instructors, using both theoretical and practical teaching components.

Each Provincial Department of Education in South Africa provided a pentile or decile rating for each school according to socioeconomic status. This ranking is based on a score derived from the number of basic facilities available to people within the immediate geographical area of each school. A high rating indicated that the majority of pupils at that school were of high socioeconomic status and visa versa. Decile rated schools were converted to a pentile rating and then schools were randomly selected from each category. This stratification provided a sample of schools which represented the range of socioeconomic status which exists in South African primary schools. As testing was initiated In the Western Cape, a larger number of schools from this region were sampled in comparison to the other provinces in South Africa.

The principal of each selected school was contacted and schools were invited to participate in the study. On acceptance of the offer, each principal was given 420 informed consent forms and asked to distribute the forms equally among the pupils within the different age groups (Grades 1 to 7). This usually resulted in cluster-like sampling as forms were distributed to a selection of classes within each grade. If a school declined the invitation to participate in the study, another school of similar socioeconomic level was randomly selected.

Ethnic distinctions were made between the children tested as follows: ‘Asian’ (those of East Asian heritage), ‘Black’ (those of African ancestry), ‘Mixed ancestry’ (those of mixed origin, a uniquely South African group), ‘White’ (those of Caucasian ancestry) and ‘Other’ (those not fitting into any of the previously identified groups). Ethnic group identification was made by members of the testing team.

The Research Ethics Committee of the University of Cape Town approved this study. Further to this, permission was obtained from each Provincial Education Department, to conduct testing at the schools within their province. Finally, prior to a child partaking in the study, written consent was required from their parent or guardian and verbal assent from each learner.

3.5 **Anthropometric Testing Protocols**

The height and weight of each child was measured. To measure height, a tape measure was attached to the wall. Each child stood with his/her back to the wall, heels touching the wall, arms at the sides, head raised and looking forward. Palms were turned inwards, resting on the thighs. The height measurement was defined as the distance from the floor to the vertex, in the mid-sagital plane. The value was recorded to the nearest 1.0 mm. Body mass was measured to the nearest 0.1 kg using an electronic scale, which was calibrated before use. The children were measured without shoes and wearing only minimal clothing. Each child was instructed to stand still, with their mass equally distributed between their feet, until the scale reading stabilised. The mass was then recorded. Body mass index (BMI) was calculated as the body weight (kilograms) divided by the height squared (meters).

3.6 **Reasons and methods of classification**

A measure of obesity based on body mass index is advantageous as height and weight can be measured with accuracy in a variety of laboratory and field settings. The method of Cole et al. (13) was used to determine cut-off points for body mass index for overweight and obesity among children. This method was developed from a large sample of international subjects (n = 192 727). Cole et al. (13) predicted the BMI at different ages which would result in an overweight (BMI = 25 $kg.m^{-2}$) or obese (BMI = 30 $kg.m^{-2}$) subject at the age of 18 years. The results from this analysis allow for international comparisons and are more appropriate than using previous methods of arbitrarily defined percentile cut-offs. This conclusion can be reached because the datasets used to derive these definitions, each consisted of over 10 000 subjects, adopted strict quality controls and originated from studies conducted in the United States (87), Great Britain (458), Hong Kong (459), Brazil (460), Singapore (461) and the Netherlands (458).

3.7 **Fitness Testing Protocol**

The children performed a general, *ad libitum*, warm-up lasting approximately five minutes, before starting any testing sessions. Prior to performing any of the tests the children were familiarised with the test protocol. The schematic describing the order of the testing is shown in Figure 7. Initially the children were divided into small groups to perform the sit-up tests, with a member of the testing team assigned to each group to demonstrate and ensure correct technique. Following this, the children were divided into four equal groups. Testing of height and body mass, standing long jump, sit-and-reach and 5-metre shuttle run were then conducted in a "round robin" format. The children sat down in rows at each testing station. After completing the test each child sat down again and rested until the next test. When all the children had been tested at each station, a whistle was blown by the person overseeing the testing, and the children moved to the next station. This was repeated until each child had performed each test. The children then formed three equal groups and were escorted to the closest sports fields to perform the cricket ball throw test (Figure 7).

SIT-UPS

↓

HEIGHT AND WEIGHT (2 stations)

↑ ↓

SHUTTLES (3 to 4 stations) SIT-AND-REACH (2 stations)

↑ ↓

STANDING LONG JUMP (3 stations)

↓

CRICKET BALL THROW (3 stations)

Figure 7: Setup used for testing children during the Health of the Nation project

3.7.1 **Sit-and-reach flexibility test**

The child sat with legs extended and feet dorsi-flexed, with the surface of the foot placed against a purpose-built wooden box. The test was performed as the child extended forwards with arms straight and tried to reach as far forward as possible. A helper held the legs to prevent them from bending. The measuring box was 33 cm high with an overhang of 50 cm. The measurement was recorded in centimetres, with 15 cm coinciding with the toes of the child. The child repeated the test twice, with the highest reading of the two (rounded to the nearest cm) recorded as the final score.

3.7.2 **Standing long jump**

The children stood barefoot with knees bent, feet together and arms back. They swung their arms and jumped as far forward as possible, landing with their feet together. Each child was given two attempts to perform the test. The better of the two scores was recorded as the test result. If a child lost balance during the test he/she was granted an additional attempt. The score was defined as the shortest distance, measured in centimetres, from the heels of the feet in the starting position to the point at which the closest heel touched the ground following the jump.

3.7.3 **Sit-ups**

The child was positioned with his/her knees bent at 90º, feet flat on the ground, hands behind the head and both shoulder blades touching the floor. A helper sat opposite the child and held his/her feet on the ground. The child sat-up and touched both knees with his/her elbows then returned to the starting position. This was repeated as many times as possible during 30 seconds. If the elbows did not touch the knees, the shoulder blades did not touch the ground or the hands were moved from behind the head, the repetition was not counted. The protocol required that the feet remained on the ground throughout the testing.

3.7.4 **5-m shuttle run test**

The marker cones were placed five metres apart. Two pieces of rope placed along the ground at these points, clearly indicated the start and finish lines of the five-metre distance. The subject started behind the rope on one side of the shuttle. After a countdown (*"3, 2, 1, start"*) the subject ran as fast as possible between the cones, crossed the line with both feet, then ran back to the starting point. The subject repeated this until he/she had completed 10 shuttles (i.e. 50 m) in as short a time as possible. The time taken to complete 10 shuttles was recorded to the nearest 0.1 seconds. If a subject did not cross the line with both feet they were penalised 0.1 seconds. If this occurred more than once they were required to repeat the test following a short rest.

The initial Western Cape fitness testing used a longer shuttle run than that usually included in the Eurofit test battery. In this case 20 shuttles were completed using the same test set up described above, resulting in each child running a distance of 100 m. When the project was expanded to a national level the testing protocol was altered to the internationally accepted Eurofit protocol thereby allowing international comparisons. However, to maintain the sample size on this test, the decision was taken to convert the 100 m shuttle run scores of the Western Cape children to a 50 m equivalent. This required additional *a posteriori* testing and validation, which are elaborated under Appendix E: Adaptations to the 5-m shuttle run test, giving a further explanation of the details related to this conversion.

3.7.5 **Cricket ball throw**

For the cricket ball throw test the child had to throw a 135 g (4.75 oz) cricket ball as far as possible. A restraining line was marked out. The child had to stand in front of this when throwing. The child was required to remain behind a second line, marked out two metres away, during the test. A run-up was allowed, provided that the child remained within the delineated two metre-area, even during the follow-through. Each child was allowed two attempts. The best throw was recorded as the score, in metres and centimetres, taken as the distance from the centre of the restraining line to the point at which the ball first bounced.

3.8 **Structure of the project**

Although all measurements were made during a single testing session for each child, this project was divided into four main parts each with their own questions and outcomes. As such, the methodology which follows is divided into four sections. Figure 8 gives an outline of these different parts.

PART 1

Nutritional Status Study

Measurements: Height, Weight, Gender, Age, Ethnicity

Outcome measures: BMI; predicted BMI at 18; Prevalence of stunting, wasting, underweight, overweight and obesity; odds ratios for nutritional factors.

Research Questions:

What is the prevalence of a range of nutritional measurements in SA children?

Are ethnic differences in nutritional status evident?

How do present SA children compare to SA children a decade ago?

How do SA children compare to children from other countries?

PART 2

Physical Fitness Study

Measurements: Sit-ups, Standing long jump, Sit-and-reach, Ball throw, Shuttle run, Gender, Age, Ethnicity

Outcome measures: Mean physical fitness measures according to ethnic group, gender and age

Research Questions:

What are the baseline levels of physical fitness in SA children?

Are there ethnic differences in physical fitness levels?

How do SA children compare to children from other countries?

PART 3

Interactions Study

Measurements: As in part 1 and 2

Outcome measures: Percentile values of anthropometric and physical fitness measures

Research Question:

To what degree does nutritional status predict test performance?

Are stunting and overweight/obesity prevalence related?

PART 4

Socioeconomic Study

Measurements: As in part 1 and 2; socioeconomic status

Outcome measures: Mean nutritional and physical fitness measures according to high and low socioeconomic status

Research Question:

What is the distribution of nutritional status and test performance according to high and low socioeconomic status?

Are some of the differences noted between ethnic groupings as a result of socioeconomic status?

Figure 8: Schematic representation of the outline of this project

3.8.1 **Part 1: Nutritional Status Study**

Both under- and over-nutrition have an effect on the health-related physical fitness test performance of children ((405); (410); (462); (463); (293)). Therefore, a study with a main focus on the health-related physical fitness in children would be incomplete without an examination of the nutritional anthropometry of the children in this sample.

Body mass index was calculated from the height and weight measurements of each learner within a Microsoft Excel spreadsheet (464). The data were then imported into a STATISTICA (465) spreadsheet and analysed. Basic statistics (mean, standard deviation and sample size for stature, mass and BMI; percentage and sample size for the other nutritional variables) were calculated for each gender, age and ethnic grouping (Table V, Table VI and Table VII). Differences between the height, mass and BMI variables were calculated using an analysis of variance (ANOVA). The Scheffé *post-hoc* test was used to determine specific differences, when the overall F value was significant. P values of $p < 0.05$ were considered statistically significant. The Scheffé *post-hoc* test has limited power and is therefore highly suited to the control of Type I errors often encountered in large sample sizes (466).

As BMI changes with age in children ((203);(92)), the WHO (2007) BMI growth chart norms (WHO 2007 (6)) were used to determine the predicted BMI at age 18 for each child. Firstly, z-scores for each required age group (6 to 13 years and 18 year olds) were converted to percentage scores. The Boltzmann sigmoidal equation was used to determine the line of best fit between each age group and their 18 year old counterparts, using GraphPad Prism 3.0 (467). Finally, BMI at age 18 was determined for each child according to these age-specific equations (Table VIII).

Each child was assessed for mild stunting, moderate stunting, underweight, wasting, and, stunting and wasting according to the WHO (2007) normative growth curve data (6). The same variables were assessed using the 1978 CDC/WHO (7) guidelines, to allow an analysis of the secular trends in nutritional status among young South Africans. Overweight and obesity prevalence were determined according to the cut-off points suggested by Cole (13).

Table IV shows the criteria used for classification of the nutritional status for each variable.

Table IV: The criteria used for the classification of the nutritional status of the children. Where specific normative growth curves are not specified, the definition is used by both normative growth curves.

Category	≤ 9 years of age	> 9 years of age
Underweight	≥ -2 SD of weight-for-age [a b]	≥ -2 SD of weight-for-age [a b]
Mildly Stunted	< -1 SD of height-for-age [a b] and ≥ -2 SD of height-for-age [a b]	< -1 SD of height-for-age [a b] ≥ -2 SD of height-for-age [a b]
Moderately stunted	< -2 SD of height-for-age [a b]	< -2 SD of height-for-age [a b]
Wasted	< -2 SD of weight-for-height [a] / < -2 SD of BMI-for-age [b]	< 5th percentile of BMI-for-age [a]/ < -2 SD of BMI-for-age [b]
Stunted and Wasted	< -2 SD of height-for-age [a b] and < -2 SD of weight-for-height [a]/ < -2 SD of BMI-for-age [b]	< -2 SD of height-for-age [a b] and < 5th percentile of BMI-for-age [a] / < -2 SD of BMI-for-age [b]
Overweight	≥ IOTF cut-off point for overweight and < IOTF cut-off point for obesity	≥ IOTF age cut-off point for overweight and < IOTF age cut-off point for obesity
Obese	≥ IOTF age cut-off point for obesity	≥ IOTF age cut-off point for obesity

Note: Definitions according to the 1978 CDC/WHO (7) norms are marked as [a], and definitions according to the WHO 2007 (6) norms are marked as [b].

The percentage of children classified as mildly stunted, moderately stunted, underweight, wasted and stunted, and wasted were calculated for each gender and age group (Table IX - Table XVIII, 'All' column), and the percentage of children above the internationally acceptable cut-off points for overweight and obesity were calculated for each gender and age group (Table XIX and Table XX , 'All' column). These calculations were also completed for gender, age and ethnic groupings (Table IX - Table XX, 'Black', 'Mixed ancestry' and 'White'). There were insufficient data to conduct a meaningful analysis in the 'Asian' and 'Other' ethnicity-specific groupings, although these data were included in the 'All' column results.

Adjusted mean values were calculated by adjusting each gender and ethnicity based age group according to the size of the sample. The mean of these values was then calculated.

The 2001 South African census data were used to determine the demographic composition of the South African population and hence, to create nationally representative scores for South African children (468). Firstly, demographically adjusted means were calculated by multiplying the mean data from the black children by 0.79, the mixed ancestry children by 0.089 and the white children by 0.096. When added together these values accounted for 97.5% of the South African populous. Due to the small sample size of other ethnic groups within the sample and the South African population as a whole, other groups were not included in the demographic adjustment. Finally, the demographically representative scores were converted to a percentage value, exclusive of other ethnic groups.

3.8.2 **Part 2: Physical Fitness Study**

Several studies have identified a progressive decline in the levels of physical fitness among children over the past two decades ((298); (299); (281)). However, secular trends in the physical fitness of South African children cannot be assessed due to the lack of baseline fitness values. This study seeks to create these baseline physical fitness measures. The choice of an appropriate field test battery to assess the physical fitness of a large sample of young children in the South African context has been discussed in the literature review (Section 2.7.4).

Sit-ups, standing long jump, sit-and-reach, cricket ball throw and shuttle run scores were analysed with STATISTICA (465). Basic descriptive statistics were calculated (mean ± standard deviation) for each variable using gender, age and ethnic groupings (Table XXIII - Table XXVII). ANOVA and the Scheffé *post-hoc* tests were used to determine significant differences between groups as described in the nutritional status study.

The mean scores for each test were calculated for each gender and age group (Table XXIII - Table XXVII, 'All' column). These calculations were also completed for gender, age and ethnic groupings (Table XXIII - Table XXVII, 'Black', 'Mixed ancestry' and 'White'). The small sample sizes of the 'Asian' and 'Other' groups had insufficient statistical power to be analysed as separate groups. These children were however included in the analysis of the 'All' category.

The data were also analysed using an analysis of covariance (ANCOVA) with height, body weight and BMI as the covariates. Significant differences between effects in all tables are indicated by a superscripted letter (b = different from black children; m = different from mixed ancestry children; w = different from white children) placed next to the given value within each table.

An average South African score for both males and females was calculated for each test, across age groups. To allow international comparisons, the South African data were used as the baseline measure and the percentage differences between this baseline and international datasets were calculated. Where data was not available for the entire age range, the comparative South African average was also only taken across the available age range in the international sample. Additionally, where both mean height and mass were available but not mean BMI, a crude mean BMI was calculated for each age group using the sample mean height and weight values (Table XXVIII).

3.8.3 **Part 3: Interactions Study**

The nutritional status of children affects their performance on tests of physical fitness. Overweight and obese children often show poorer test scores then their normal weight counterparts on tests which require them to move their body weight ((405); (410); (462)). On the other hand, under-nourishment during the growth of children may result in functional impairments in the fast-twitch muscle fibres without affecting the slow-twitch muscle fibres ((463); (293)). Research has also shown that children who are stunted may be at an increased risk of becoming overweight or obese if exposed to improved socioeconomic conditions ((22); (41); (188)). Therefore, this study aimed to examine the interactions between body size, nutritional status and physical fitness.

In order to control for body size and test specific differences according to age, the percentile scores for the performance of each child on each test were calculated. The data of the children were initially entered into a spreadsheet and grouped by gender, then age, using Microsoft Excel (464). The data from each sub-group was imported into a STATISTICA (465) spreadsheet and analysed through the frequency table facility. Through this, the data were divided into percentiles. The data was then graphed using GraphPad Prism 3.0 (467) and a line of best fit was calculated using the Boltzmann Sigmoidal equation: Y = Bottom + (Top-Bottom)/(1+exp((V50-X)/slope) (Figure 9). This equation, defining the line of best fit for each sub-group of data, was programmed into purpose made computer software. This software automated the calculation of age and gender specific percentile scores for each variable.

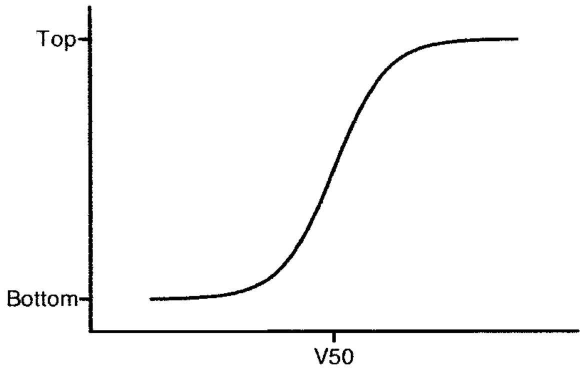

Figure 9: Diagram of the Boltzmann Sigmoidal curve

STATISTICA was also utilized in further data analysis (465). Multivariate Exploratory analysis was used to determine whether it would be appropriate to create a combined fitness score from the five fitness tests (Table XXIX). As this showed low inter-item correlations and a weak chronbach alpha, the fitness test scores were analysed separately. A Pearson Product-Moment correlation matrix was created to provide an overview of the interactions between the different variables (Table XXX). In this analysis, weight status (obesity and overweight or normal weight) was treated as a categorical variable, as were stunting, gender, and socioeconomic status classification. The continuous variables included: age; predicted BMI at 18 years of age; and the percentile values of each child for height, mass, BMI, standing jump, shuttle run, sit-ups, ball throw and sit-and-reach. These correlation coefficients were squared to calculate the coefficients of determination and are recorded in (Table XXXI).

General linear models were used to assess whether there were differences between the physical fitness test scores of children with nutritional deficiencies or excesses, and those of normal BMI-for-age, height-for-age and weight-for-age. Gender, age, ethnicity and socioeconomic status were used as co-variates in this analysis (Figure 11 - Figure 15). A comparison was also made between the prevalence of overweight and obesity in boys and girls who were mildly or moderately stunted and those who were of normal height-for-weight (Figure 16).

3.8.4 **Part 4: Socioeconomic Study**

Although many studies have identified significant differences between different ethnic groups in physical activity levels and fitness test performance ((436); (437); (432); (433)), socioeconomic status may account for some of these differences (438). This study considered differences in anthropometric status, nutritional status and physical fitness between socioeconomic groups.

The legacy of apartheid has resulted in the unequal distribution of the various ethnic groups across the socioeconomic strata within South Africa. The majority of white children fall into the highest socioeconomic group and hence a comparison between white high and low socioeconomic children could not be made. Although the majority of children comprising the lowest socioeconomic group in South Africa are black, this socioeconomic level also contains a small proportion of mixed ancestry children. Since the abolition of apartheid, a larger proportion of black and mixed ancestry children are able to attend schools classified in the highest socioeconomic strata, yet their relative numbers are still small in comparison to white children.

Nutritional status according to socioeconomic and ethnic groupings was assessed by considering differences in the proportion of children classified as nutritionally deficient. To determine if socioeconomic differences had a bearing on the previously identified ethnic differences, these comparisons of the anthropometric and fitness variables were made between black and mixed ancestry children of high and low socioeconomic status. Children from different ethnic groups but the same socioeconomic group were also compared to each other. Data analysis was performed using factorial ANOVAs, grouping according to socioeconomic status and ethnic group. Due to the unequal and in some cases, small sample size of this comparison, the Unequal N HSD *post-hoc* test was used to determine specific differences, when the overall F value was significant. P values of $p < 0.05$ were considered as statistically significant (Table XXXII - Table XLV, Table XLIX - Table LXIV and Figure 17 - Figure 24).

3.9 **Conclusion**

This chapter has outlined the objectives of each study conducted in this dissertation. It has also described the methodology and data analysis techniques used to assess the different questions raised by each study.

CHAPTER 4

RESULTS

4.1 **Introduction**

This dissertation aims to describe the nutritional status and health-related fitness of children in South African. Considering the inequalities between ethnic groups resulting from historical South African legislation, an analysis of this kind would be incomplete without examining whether these variables were influenced by ethnic and socioeconomic factors.

The following chapter presents the results of this dissertation and is divided into four different parts. Each part starts with a brief summary of the purpose and methods of the study and includes the results relevant to the section. An overview of the main findings is provided at the end of the chapter.

4.2 **Part 1: Nutritional Status Study**

The nutritional section of this thesis examines the anthropometric variables of height, mass and BMI as an indicator of nutritional status. The prevalence rates of mild and moderate stunting, wasting, stunting and wasting, and underweight were calculated according to the WHO 2007 (6) and the 1978 CDC/WHO (7) growth curves. Overweight and obesity prevalence were assessed using the IOTF cut-off points. These were all reported according to ethnic group, the full sample, and a demographic adjustment which provided national South African prevalence rates. To gain an understanding of how the South African overweight and obesity prevalence rates compare on an international scale, these values were compared to the data reported from a number of other countries which used the IOTF cut-offs for classification. The odds ratios of the occurrence of the reported nutritional anthropometric conditions in the different ethnic groups, as a function of the demographically-adjusted prevalence rates in the South African population, are also reported. Significant differences in each table are indicated by a superscripted letter (^{b} = different from black children; ^{m} = different from mixed ancestry children; ^{w} = different from white children) placed next to the given value.

Table V shows the heights of the children in the sample. Among the boys there was a significant interaction between age and ethnicity ($F = 2.0$; $P < 0.013$). The height of the boys increased significantly in all groups each year ($F = 1185.0$; $P < 0.0000001$). There was a significant difference in height between ethnic groups ($F = 490.0$; $P < 0.0000001$) with the white boys being tallest and the black boys shortest. The heights of the girls increased significantly in all groups each year ($F = 1358.0$; $P < 0.0000001$). There was a significant difference in height between ethnic groups ($F = 358.0$; $P < 0.0000001$) with the white girls being tallest and the black girls shortest (Table V). However, there was no difference in the rate of change of height with age, between the different ethnicities (Non-significant interaction: $F = 1.0$; $P < 0.11$).

The mass data for the boys (Table VI) showed a successive increase in mass with each year in all groups ($F = 418.0$; $P < 0.0000001$), except between 6 and 7 years of age. There was a significant difference in mass between the different ethnic groups ($F = 220.9$; $P < 0.0000001$) with the white boys heaviest and the black boys the lightest in most cases (Table VI). There was a significant interaction between age and ethnic group among the boys ($F = 4.0$; $P < 0.000001$). The rate of change of mass with increasing age was different between ethnicities among the girls (a significant interaction: $F = 2.4$; $P < 0.002$). There was a significant difference in mass between ethnic groups ($F = 73.5$; $P < 0.0000001$) except between the black and mixed ancestry girls (Table VI). The white girls were heavier than the other two groups. The mass increased significantly in all groups each year ($F = 491.9$; $P < 0.0000001$) from 7 years onwards.

Table VII shows that BMI changed significantly with age in the boys ($F = 57.0$, $p < 0.0000001$) and from 9 years of age among the girls ($F = 74.4$, $p < 0.0000001$). The difference in BMI between ethnic groups was significant ($F = 59.5$, $p < 0.0000001$), with the white boys displaying the highest BMI at any given age. The group of girls also showed a significant interaction between age and ethnicity for BMI ($F = 2.3$, $p < 0.003684$). Initially the white girls had the highest BMI values but this trend changed after 11 years of age. A significant interaction was evident between age and ethnicity for BMI for the boys ($F = 1.7$, $p < 0.046534$) and the girls ($F = 16.8$, $p < 0.0000001$).

Descriptive data for the predicted BMI at 18 years of age is shown in Table VIII. The predicted BMI at 18 years of age differed significantly between the age groups among the boys ($F = 5.0$, $p < 0.000011$). This trend did not occur among the girls ($F = 1.1$, $p < 0.372383$). Among the boys, there was a significant difference between the ethnic groups ($F = 85.4$, $p < 0.0000001$), with the white boys showing higher values for predicted BMI at 18 years than the mixed ancestry and black children. Significant differences between all ethnic groups, except the black and white children, were evident for girls ($F = 16.3$, $p < 0.0000001$). Predicted BMI at 18 years of age changed at a different rate with age between the different ethnic groups in both the boys ($F = 2.0$, $p < 0.013173$) and the girls ($F = 1.9$, $p < 0.025287$).

To determine whether the chosen norms were suitable for use without correction for differences in maturational status, the mean z-scores and centile values for the height-for-age and weight-for-age of the current South African sample were calculated using the Epi Info (469) software package, according to the 1978 CDC/WHO (7). This analysis revealed z-scores of 0.1 ± 1.3 and 0.1 ± 1.2, and centile scores of 53.0 ± 32.5 and 50.3 ± 31.0 for height-for-age for the boys and girls respectively. The weight-for-height z-score values were 0.0 ± 1.2 and 0.1 ± 1.4, and the centile values were 48.0 ± 29.2 and 50.3 ± 31.0, for boys and girls respectively. As the means were close to the zero z-score and the centiles were close to the 50th percentile, this was deemed a suitable reference population for the current sample. Seeing that the WHO 2007 (6) curves are based on the same main sample population as the 1978 CDC/WHO (7) dataset it was not necessary to repeat this analysis for this reference.

Table V: Stature (cm) of black, mixed ancestry and white children (6 to 13 years). Values are expressed as means ± SD and sample size (n).

Age (yrs)	Boys				Girls			
	Black	**Mixed ancestry**	**White**	**All**	**Black**	**Mixed ancestry**	**White**	**All**
6	115.8 ± 4.9 *(94)*	117.4 ± 4.9 *(42)* ^{w}	122.8 ± 4.8 *(51)* ^{m}	118.0 ± 6.0 *(200)*	115.8 ± 5.4 (102)	118.8 ± 5.4 (57)	122.0 ± 5.0 (51)	117.9 ± 5.9 (220)
7	119.6 ± 6.1 *(223)* ^{w}	122.5 ± 5.6 *(70)*	125.8 ± 5.6 *(134)* ^{b}	122.0 ± 6.5 *(447)*	119.6 ± 5.8 (251) ^{w}	122.6 ± 6.8 (92)	126.5 ± 5.5 (143) ^{b}	122.3 ± 6.6 (500)
8	125.3 ± 6.1 *(297)* ^{w}	129.2 ± 6.2 *(82)*	133.2 ± 6.6 *(200)* ^{b}	128.7 ± 7.2 *(607)*	124.3 ± 5.9 (297) ^{w}	129.2 ± 6.4 (75)	131.3 ± 5.8 (199) ^{b}	127.4 ± 6.7 (590)
9	129.9 ± 6.6 *(295)* ^{w}	133.6 ± 7.0 *(153)*	138.0 ± 6.4 *(276)* ^{b}	133.8 ± 7.5 *(749)*	130.1 ± 6.3 (290) $^{m\ w}$	134.8 ± 7.6 (128) ^{b}	137.5 ± 6.2 (219) ^{b}	133.5 ± 7.3 (647)
10	136.1 ± 6.8 *(384)* ^{w}	138.9 ± 6.5 *(172)* ^{w}	143.3 ± 7.2 *(300)* $^{b\ m}$	139.2 ± 7.6 *(889)*	136.8 ± 7.4 (361) ^{w}	140.6 ± 8.3 (132)	143.4 ± 7.5 (205) ^{b}	139.3 ± 8.1 (727)
11	139.7 ± 7.4 *(369)* $^{m\ w}$	144.0 ± 7.5 *(188)* $^{b\ w}$	148.6 ± 6.9 *(419)* $^{b\ m}$	144.3 ± 8.2 *(1009)*	142.4 ± 7.5 (389) $^{m\ w}$	146.3 ± 8.1 (175) ^{b}	149.5 ± 8.0 (175) ^{b}	145.0 ± 8.2 (757)
12	145.0 ± 8.3 *(397)* $^{m\ w}$	149.9 ± 8.8 *(159)* $^{b\ w}$	154.6 ± 8.2 *(470)* $^{b\ m}$	150.1 ± 9.4 *(1059)*	148.2 ± 7.5 (404) $^{m\ w}$	152.2 ± 7.3 (173) ^{b}	156.4 ± 6.9 (180) ^{b}	151.1 ± 8.0 (779)
13	150.5 ± 8.6 *(354)* ^{w}	153.8 ± 9.5 *(66)* ^{w}	160.0 ± 8.7 *(214)* $^{b\ m}$	154.1 ± 9.9 *(649)*	152.8 ± 7.9 (331) ^{w}	153.3 ± 6.5 (48) ^{w}	161.0 ± 5.8 (76) $^{b\ m}$	154.2 ± 8.0 (463)
Adjusted Mean	**135.8 *(2413)***	**138.9 *(932)***	**145.3 *(2064)***	**139.9 *(5609)***	**136.8 (2425)**	**139.6 (880)**	**141.4 (1248)**	**138.5 (4683)**

Table VI: Mass (kg) of black, mixed ancestry and white children (6 to 13 years). Values are expressed as means ± SD and sample size (n).

Age (yrs)	Boys				Girls			
	Black	**Mixed ancestry**	**White**	**All**	**Black**	**Mixed ancestry**	**White**	**All**
6	20.9 ± 3.1 (97)	20.6 ± 3.3 (42)	25.1 ± 5.3 (51)	22.0 ± 4.6 (203)	20.5 ± 3.4 (103)	21.5 ± 5.1 (57)	23.8 ± 4.4 (51)	21.5 ± 4.3 (221)
7	22.5 ± 3.5 (223)	22.9 ± 3.7 (70)	26.2 ± 4.4 (134)	23.7 ± 4.2 (447)	22.9 ± 4.2 (251)	23.6 ± 6.8 (93)	26.2 ± 5.3 (143)	24.0 ± 5.4 (501)
8	25.3 ± 4.5 (297) ^{w}	26.1 ± 4.4 (82)	30.1 ± 5.4 (200) ^{b}	27.1 ± 5.3 (607)	25.3 ± 4.8 (297)	26.9 ± 6.0 (75)	28.6 ± 6.0 (199)	26.7 ± 5.6 (590)
9	27.2 ± 4.9 (295) ^{w}	29.3 ± 7.2 (153)	32.4 ± 7.1 (275) ^{b}	29.6 ± 6.8 (748)	28.2 ± 6.0 (290)	30.0 ± 7.1 (128)	32.3 ± 6.6 (219)	29.9 ± 6.7 (647)
10	31.7 ± 6.8 (384) ^{w}	32.9 ± 8.2 (172)	36.9 ± 9.1 (301) ^{b}	33.8 ± 8.4 (890)	33.3 ± 8.1 (361)	34.1 ± 9.2 (132)	37.4 ± 9.3 (205)	34.5 ± 8.8 (727)
11	33.7 ± 7.2 (369) ^{w}	36.4 ± 9.0 (188) ^{w}	40.7 ± 9.0 (418) $^{b\ m}$	37.2 ± 9.1 (1008)	37.1 ± 8.6 (389) ^{w}	38.8 ± 9.9 (175)	41.8 ± 10.0 (175) ^{b}	38.6 ± 9.4 (757)
12	37.9 ± 8.2 (397) ^{w}	39.9 ± 8.7 (159) ^{w}	44.7 ± 10.4 (470) $^{b\ m}$	41.4 ± 10.0 (1059)	42.8 ± 9.1 (404)	42.5 ± 9.7 (173)	46.9 ± 11.4 (180)	43.7 ± 10.1 (779)
13	41.5 ± 9.8 (354) ^{w}	41.1 ± 10.0 (66) ^{w}	50.7 ± 11.7 (214) $^{b\ m}$	44.6 ± 11.5 (649)	48.0 ± 10.5 (330)	42.7 ± 6.8 (48)	50.4 ± 8.4 (76)	47.9 ± 10.1 (462)
Adjusted Mean	**31.8 (2416)**	**32.9 (932)**	**38.6 (2063)**	**34.6 (5611)**	**34.3 (2425)**	**34.0 (881)**	**36.0 (1248)**	**34.7 (4684)**

Table VII: BMI (kg.m^{-2}) of black, mixed ancestry and white children (6 to 13 years). Values are expressed as means ± SD and sample size (n).

Age (yrs)	Boys				Girls			
	Black	**Mixed ancestry**	**White**	**All**	**Black**	**Mixed ancestry**	**White**	**All**
6	15.8 ± 1.5 (94)	15.0 ± 1.8 (42)	16.6 ± 2.5 (51)	15.9 ± 2.1 (200)	15.5 ± 1.7 (101)	15.2 ± 2.9 (57)	16.0 ± 2.2 (51)	15.5 ± 2.2 (219)
7	15.8 ± 1.5 (223)	15.4 ± 1.8 (69)	16.6 ± 1.9 (134)	16.0 ± 1.8 (445)	16.1 ± 2.2 (251)	15.7 ± 3.2 (92)	16.4 ± 2.7 (143)	16.1 ± 2.6 (500)
8	16.2 ± 2.0 (297)	15.7 ± 1.8 (82)	17.0 ± 2.2 (200)	16.4 ± 2.1 (607)	16.5 ± 2.6 (297)	16.1 ± 3.0 (75)	16.5 ± 2.8 (199)	16.5 ± 2.7 (590)
9	16.2 ± 2.3 (295)	16.3 ± 2.7 (153)	17.0 ± 2.7 (275)	16.5 ± 2.6 (748)	16.7 ± 2.8 (290)	16.4 ± 2.7 (128)	17.1 ± 2.8 (219)	16.8 ± 2.8 (647)
10	17.2 ± 2.7 (384)	17.0 ± 3.2 (172)	17.9 ± 3.2 (300)	17.4 ± 3.1 (889)	17.8 ± 3.1 (360)	17.1 ± 3.3 (132)	18.1 ± 3.4 (205)	17.7 ± 3.2 (726)
11	17.3 ± 2.6 (368)	17.5 ± 3.4 (188)	18.4 ± 3.2 (418)	17.8 ± 3.1 (1007)	18.3 ± 3.3 (389)	18.1 ± 3.9 (175)	18.6 ± 3.5 (175)	18.3 ± 3.5 (757)
12	18.1 ± 2.8 (396)	17.7 ± 2.8 (159)	18.6 ± 3.2 (470)	18.3 ± 3.1 (1058)	19.6 ± 3.5 (404)	18.3 ± 3.5 (173)	19.1 ± 4.0 (180)	19.1 ± 3.7 (779)
13	18.3 ± 3.0 (354)	17.3 ± 2.9 (66) [w]	19.7 ± 3.3 (214) [m]	18.7 ± 3.3 (649)	20.7 ± 4.1 (330)	18.2 ± 2.2 (48)	19.5 ± 2.8 (76)	20.2 ± 3.8 (462)
Adjusted Mean	**17.1 (2411)**	**16.8 (931)**	**18.0 (2062)**	**17.4 (5603)**	**18.0 (2422)**	**17.1 (880)**	**17.7 (1248)**	**17.7 (4680)**

Table VIII: Predicted BMI at 18 years (kg.m^{-2}) of black, mixed ancestry and white children (6 to 13 years). Values are expressed as means ± SD and sample size (n).

Age (yrs)	Boys				Girls			
	Black	**Mixed ancestry**	**White**	**All**	**Black**	**Mixed ancestry**	**White**	**All**
6	22.6 ± 3.4 (94)	21.2 ± 4.0 (42)	24.7 ± 6.2 (51)	22.9 ± 4.9 (200)	21.3 ± 3.5 (101)	21.2 ± 5.6 (57)	22.6 ± 4.2 (51)	21.6 ± 4.3 (219)
7	22.1 ± 3.0 (223)	21.4 ± 4.5 (69)	23.8 ± 3.9 (134)	22.4 ± 3.8 (445)	22.0 ± 3.9 (251)	21.4 ± 5.7 (92)	22.7 ± 4.7 (143)	22.1 ± 4.6 (500)
8	22.3 ± 3.6 (297)	21.4 ± 3.2 (82)	23.7 ± 4.0 (200)	22.6 ± 3.9 (607)	22.0 ± 4.1 (297)	21.5 ± 4.7 (75)	22.3 ± 4.6 (199)	22.1 ± 4.4 (590)
9	21.6 ± 3.4 (295)	21.8 ± 4.3 (153)	22.9 ± 4.3 (275)	22.1 ± 4.0 (748)	21.6 ± 4.0 (290)	21.2 ± 4.1 (128)	22.3 ± 4.2 (219)	21.7 ± 4.1 (647)
10	22.3 ± 3.9 (384)	22.1 ± 4.4 (172)	23.4 ± 4.6 (300)	22.7 ± 4.3 (889)	22.2 ± 4.2 (360)	21.4 ± 4.4 (132)	22.8 ± 4.4 (205)	22.1 ± 4.3 (726)
11	21.7 ± 3.5 (368)	22.0 ± 4.4 (188)	23.3 ± 4.2 (418)	22.4 ± 4.1 (1007)	21.9 ± 4.1 (389)	21.6 ± 4.8 (175)	22.4 ± 4.3 (175)	22.0 ± 4.3 (757)
12	21.8 ± 3.5 (396)	21.4 ± 3.6 (159)	22.6 ± 4.0 (470)	22.2 ± 3.8 (1058)	22.4 ± 4.0 (404)	21.0 ± 4.1 (173)	22.0 ± 4.5 (180)	22.0 ± 4.2 (779)
13	21.2 ± 3.6 (354)	20.0 ± 3.5 (66)	23.0 ± 3.8 (213)	21.6 ± 3.8 (649)	22.7 ± 4.4 (330)	20.0 ± 2.6 (48)	21.5 ± 3.2 (76)	22.2 ± 4.2 (462)
Adjusted Mean	**21.9 (2411)**	**21.6 (931)**	**23.2 (2062)**	**22.3 (5603)**	**22.1 (2422)**	**21.3 (880)**	**22.4 (1248)**	**22.0 (4680)**

Table IX: Percentage of mild stunting (height-for-age < -1 z-score) black, mixed ancestry and white boys (6 to 13 years). Values are expressed as percentages and sample size (n).

Age (yrs)	Black		Mixed ancestry		White		All		Demographic Adjustment	
	WHO (2007)	CDC/WHO (1978)	WHO (2007)	CDC/WHO (1978)	WHO (2007)	CDC/WHO (1978)	WHO (2007)	CDC/WHO (1978)	WHO (2007)	CDC/WHO (1978)
6	28.7 (94)	14.9 (94)	23.8 (42)	9.5 (42)	2.0 (51)	0.0 (51)	19.6 (199)	10.1 (199)	24.4 (187)	12.3 (187)
7	34.1 (223)	22.9 (223)	14.3 (70)	12.9 (70)	12.7 (134)	3.7 (134)	24.2 (447)	15.2 (447)	28.7 (427)	19.1 (427)
8	32.0 (297)	18.5 (297)	17.1 (82)	9.8 (82)	8.5 (200)	2.0 (200)	21.6 (607)	11.4 (607)	26.9 (579)	15.3 (579)
9	31.2 (295)	25.8 (295)	20.3 (153)	17.6 (153)	3.6 (276)	1.1 (276)	18.0 (749)	14.4 (749)	26.1 (724)	21.5 (724)
10	25.3 (384)	18.5 (384)	16.9 (172)	9.3 (172)	6.7 (300)	3.0 (300)	16.8 (889)	11.4 (889)	21.6 (856)	15.3 (856)
11	35.0 (369)	26.0 (369)	23.9 (188)	11.7 (188)	7.2 (419)	2.9 (419)	20.7 (1009)	13.3 (1009)	29.7 (976)	21.3 (976)
12	37.8 (397)	29.7 (397)	29.6 (159)	20.8 (159)	12.1 (470)	4.9 (470)	25.0 (1059)	17.4 (1059)	32.8 (1026)	25.1 (1026)
13	36.7 (354)	31.6 (354)	28.8 (66)	31.8 (66)	18.7 (214)	7.5 (214)	29.6 (648)	23.6 (648)	32.5 (634)	27.8 (634)
Adjusted Mean	**33.0 (2413)**	**24.5 (2413)**	**22.0 (932)**	**15.0 (932)**	**9.3 (2064)**	**3.5 (2064)**	**21.9 (5607)**	**14.9 (5607)**	**28.2 (5409)**	**20.5 (5409)**

Table X: Percentage of mild stunting (height-for-age < -1 z-score) black, mixed ancestry and white girls (6 to 13 years). Values are expressed as percentages and sample size (n).

Age (yrs)	Black		Mixed ancestry		White		All		Demographic Adjustment	
	WHO (2007)	CDC/WHO (1978)	WHO (2007)	CDC/WHO (1978)	WHO (2007)	CDC/WHO (1978)	WHO (2007)	CDC/WHO (1978)	WHO (2007)	CDC/WHO (1978)
6	21.6 (102)	10.8 (102)	10.5 (57)	3.5 (57)	3.9 (51)	0.0 (51)	14.5 (220)	6.8 (220)	17.9 (210)	8.6 (210)
7	27.1 (251)	21.9 (251)	16.3 (92)	14.1 (92)	2.8 (143)	0.7 (143)	18.0 (500)	14.0 (500)	22.6 (486)	18.2 (486)
8	31.0 (297)	22.6 (297)	6.7 (75)	1.3 (75)	5.0 (199)	2.5 (199)	19.3 (590)	12.5 (590)	24.9 (571)	17.8 (571)
9	34.8 (290)	16.9 (290)	18.8 (128)	7.8 (128)	7.3 (219)	1.8 (219)	22.3 (647)	9.9 (647)	29.1 (637)	13.9 (637)
10	31.6 (361)	18.6 (361)	24.2 (132)	10.6 (132)	15.1 (205)	3.9 (205)	25.7 (727)	12.5 (727)	27.9 (698)	15.6 (698)
11	29.6 (389)	19.8 (389)	17.7 (175)	12.0 (175)	15.4 (175)	5.7 (175)	23.1 (757)	14.4 (757)	25.8 (739)	16.8 (739)
12	31.9 (404)	20.8 (404)	16.8 (173)	9.8 (173)	11.1 (180)	3.9 (180)	23.4 (779)	14.4 (779)	27.1 (757)	17.2 (757)
13	32.3 (331)	29.3 (331)	22.9 (48)	20.8 (48)	2.6 (76)	2.6 (76)	26.6 (463)	24.2 (463)	27.1 (455)	24.6 (455)
Adjusted Mean	**30.8 (2425)**	**20.9 (2425)**	**17.4 (880)**	**10.0 (880)**	**9.0 (1248)**	**3.0 (1248)**	**22.4 (4683)**	**13.8 (4683)**	**26.1 (4553)**	**17.2 (4553)**

Table XI: Percentage of moderate stunting (height-for-age < -2 z-score) black, mixed ancestry and white boys (6 to 13 years). Values are expressed as percentages and sample size (n).

Age (yrs)	Black		Mixed ancestry		White		All		Demographic Adjustment	
	WHO (2007)	CDC/WHO (1978)	WHO (2007)	CDC/WHO (1978)	WHO (2007)	CDC/WHO (1978)	WHO (2007)	CDC/WHO (1978)	WHO (2007)	CDC/WHO (1978)
6	5.3 (94)	2.1 (94)	2.4 (42)	2.4 (42)	0.0 (51)	0.0 (51)	4.0 (199)	2.0 (199)	4.3 (187)	1.8 (187)
7	14.8 (223)	8.5 (223)	7.1 (70)	1.4 (70)	1.5 (134)	0.0 (134)	9.2 (447)	4.7 (447)	12.2 (427)	6.7 (427)
8	12.1 (297)	7.7 (297)	6.1 (82)	3.7 (82)	1.0 (200)	0.5 (200)	7.1 (607)	4.4 (607)	9.9 (579)	6.3 (579)
9	12.5 (295)	4.7 (295)	4.6 (153)	1.3 (153)	1.4 (276)	0.4 (276)	6.4 (749)	2.3 (749)	10.2 (724)	3.8 (724)
10	10.7 (384)	6.8 (384)	4.1 (172)	1.7 (172)	1.7 (300)	1.0 (300)	6.3 (889)	3.6 (889)	8.8 (856)	5.5 (856)
11	16.3 (369)	7.9 (369)	4.3 (188)	2.7 (188)	1.0 (419)	0.2 (419)	7.4 (1009)	3.7 (1009)	13.0 (976)	6.3 (976)
12	17.4 (397)	10.1 (397)	6.3 (159)	1.3 (159)	1.1 (470)	0.6 (470)	8.1 (1059)	4.2 (1059)	14.1 (1026)	7.9 (1026)
13	25.1(354)	9.9 (354)	19.7 (66)	1.5 (66)	2.8 (214)	0.5 (214)	17.3 (648)	5.9 (648)	21.3 (634)	7.8 (634)
Adjusted Mean	**15.3 (2413)**	**7.8 (2413)**	**6.0 (932)**	**1.9 (932)**	**1.4 (2064)**	**0.5 (2064)**	**8.4 (5607)**	**3.9 (5607)**	**12.4 (5409)**	**6.2 (5409)**

Table XII: Percentage of moderate stunting (height-for-age < -2 z-score) black, mixed ancestry and white girls (6 to 13 years). Values are expressed as percentages and sample size (n).

Age (yrs)	Black		Mixed ancestry		White		All		Demographic Adjustment	
	WHO (2007)	CDC/WHO (1978)	WHO (2007)	CDC/WHO (1978)	WHO (2007)	CDC/WHO (1978)	WHO (2007)	CDC/WHO (1978)	WHO (2007)	CDC/WHO (1978)
6	6.9 (102)	2.0 (102)	1.8 (57)	0.0 (57)	0.0 (51)	0.0 (51)	4.5 (220)	0.9 (220)	5.5 (210)	1.5 (210)
7	10.4 (251)	2.0 (251)	7.6 (92)	1.1 (92)	0.0 (143)	0.0 (143)	6.6 (500)	1.2 (500)	8.7 (486)	1.6 (486)
8	11.8 (297)	5.7 (297)	4.0 (75)	2.7 (75)	1.0 (199)	0.5 (199)	6.8 (590)	3.4 (590)	9.5 (571)	4.7 (571)
9	11.0 (290)	5.2 (290)	2.3 (128)	1.6 (128)	0.5 (219)	0.5 (219)	5.6 (647)	2.8 (647)	8.7 (637)	4.2 (637)
10	11.9 (361)	3.9 (361)	4.5 (132)	2.3 (132)	1.0 (205)	0.5 (205)	7.3 (727)	2.8 (727)	9.7 (698)	3.3 (698)
11	14.9 (389)	6.4 (389)	6.9 (175)	1.7 (175)	2.3 (175)	0.6 (175)	9.9 (757)	3.8 (757)	12.3 (739)	5.1 (739)
12	13.9 (404)	7.4 (404)	7.5 (173)	3.5 (173)	1.1 (180)	1.1 (180)	9.2 (779)	4.9 (779)	11.5 (757)	6.1 (757)
13	10.9 (331)	8.5 (331)	8.3 (48)	6.3 (48)	0.0 (76)	0.0 (76)	8.6 (463)	6.7 (463)	9.1 (455)	7.1 (455)
Adjusted Mean	**12.1 (2425)**	**5.6 (2425)**	**5.6 (880)**	**2.4 (880)**	**0.9 (1248)**	**0.5 (1248)**	**7.7 (4683)**	**3.5 (4683)**	**9.9 (4553)**	**4.6 (4553)**

Table XIII: Percentage of wasting (BMI-for-age < -2 z-score/ weight-for-height < -2 z-score) black, mixed ancestry and white boys (6 to 13 years). Values are expressed as percentages and sample size (n).

Age (yrs)	Black		Mixed ancestry		White		All		Demographic Adjustment	
	WHO (2007)	CDC/WHO (1978)	WHO (2007)	CDC/WHO (1978)	WHO (2007)	CDC/WHO (1978)	WHO (2007)	CDC/WHO (1978)	WHO (2007)	CDC/WHO (1978)
6	4.3 (94)	2.1 (94)	7.1 (42)	7.1 (42)	2.0 (51)	2.0 (51)	4.0 (199)	3.0 (199)	4.1 (187)	2.4 (187)
7	2.7 (223)	1.3 (223)	7.2 (69)	5.8 (69)	2.2 (134)	2.2 (134)	4.0 (446)	2.9 (446)	2.9 (426)	1.7 (426)
8	3.4 (297)	1.7 (297)	8.5 (82)	4.9 (82)	3.5 (200)	3.5 (200)	4.4 (607)	3.1 (607)	3.7 (579)	2.1 (579)
9	6.1 (295)	4.4 (295)	6.5 (153)	4.6 (153)	5.1 (275)	3.6 (275)	6.3 (748)	4.4 (748)	5.7 (723)	4.1 (723)
10	4.4 (384)	7.0 (384)	8.1 (172)	12.2 (172)	5.7 (300)	9.0 (300)	5.8 (889)	8.9 (889)	4.6 (856)	7.3 (856)
11	6.0 (369)	10.8 (369)	8.0 (188)	11.7 (188)	4.3 (418)	6.5 (418)	6.2 (1008)	9.6 (1008)	5.7 (975)	9.9 (975)
12	5.5 (397)	8.6 (397)	7.5 (159)	10.7 (159)	4.7 (470)	7.7 (470)	5.9 (1059)	8.9 (1059)	5.3 (1026)	8.3 (1026)
13	10.7 (354)	15.5 (354)	19.7 (66)	27.3 (66)	4.2 (214)	4.7 (214)	9.7 (648)	13.4 (648)	10.3 (634)	14.7 (634)
Adjusted Mean	**5.7 (2413)**	**7.4 (2413)**	**8.5 (931)**	**10.3 (931)**	**4.4 (2062)**	**5.9 (2062)**	**6.0 (5604)**	**7.6 (5604)**	**5.5 (5406)**	**7.1 (5406)**

Table XIV: Percentage of wasting (BMI-for-age < -2 z-score/ weight-for-height < -2 z-score) black, mixed ancestry and white girls (6 to 13 years). Values are expressed as percentages and sample size (n).

Age (yrs)	Black		Mixed ancestry		White		All		Demographic Adjustment	
	WHO (2007)	CDC/WHO (1978)	WHO (2007)	CDC/WHO (1978)	WHO (2007)	CDC/WHO (1978)	WHO (2007)	CDC/WHO (1978)	WHO (2007)	CDC/WHO (1978)
6	2.0 (102)	2.0 (102)	14.0 (57)	12.3 (57)	5.9 (51)	5.9 (51)	5.9 (220)	5.5 (220)	3.3 (210)	3.2 (210)
7	3.2 (251)	3.2 (251)	14.1 (92)	12.0 (92)	4.9 (143)	5.6 (143)	5.8 (500)	5.6 (500)	4.1 (486)	4.0 (486)
8	4.4 (297)	3.7 (297)	9.3 (75)	6.7 (75)	8.5 (199)	6.5 (199)	6.6 (590)	5.1 (590)	5.0 (571)	4.0 (571)
9	4.8 (290)	2.1 (290)	5.5 (128)	1.6 (128)	4.6 (219)	2.3 (219)	5.1 (647)	2.3 (647)	4.6 (637)	2.0 (637)
10	2.5 (360)	4.4 (360)	4.5 (132)	11.4 (132)	3.4 (205)	6.3 (205)	3.4 (726)	6.9 (726)	2.6 (697)	5.0 (697)
11	3.6 (389)	5.9 (389)	5.7 (175)	11.4 (175)	5.1 (175)	7.4 (175)	4.4 (757)	7.8 (757)	3.7 (739)	6.2 (739)
12	2.5 (404)	4.2 (404)	8.7 (173)	10.4 (173)	3.3 (180)	6.1 (180)	4.4 (779)	6.3 (779)	3.0 (757)	4.7 (757)
13	3.3 (330)	3.3 (330)	4.2 (48)	6.3 (48)	3.9 (76)	5.3 (76)	3.5 (462)	3.9 (462)	3.3 (454)	3.6 (454)
Adjusted Mean	**3.3 (2423)**	**3.9 (2423)**	**7.7 (880)**	**9.2 (880)**	**5.0 (1248)**	**5.6 (1248)**	**4.8 (4681)**	**5.6 (4681)**	**3.7 (4551)**	**4.3 (4551)**

Table XV: Percentage of stunted and wasted black, mixed ancestry and white boys (6 to 13 years). Values are expressed as percentages and sample size (n).

Age (yrs)	Black		Mixed ancestry		White		All		Demographic Adjustment	
	WHO (2007)	CDC/WHO (1978)	WHO (2007)	CDC/WHO (1978)	WHO (2007)	CDC/WHO (1978)	WHO (2007)	CDC/WHO (1978)	WHO (2007)	CDC/WHO (1978)
6	0.0 (94)	0.0 (94)	0.0 (42)	0.0 (42)	0.0 (51)	0.0 (51)	0.0 (199)	0.0 (199)	0.0 (187)	0.0 (187)
7	0.0 (223)	0.0 (223)	1.4 (69)	1.4 (69)	0.0 (134)	0.0 (134)	0.2 (446)	0.2 (446)	0.1 (426)	0.1 (426)
8	0.7 (297)	0.0 (297)	1.2 (82)	0.0 (82)	0.0 (200)	0.0 (200)	0.5 (607)	0.0 (607)	0.6 (579)	0.0 (579)
9	0.7 (295)	0.0 (295)	0.0 (153)	0.0 (153)	0.0 (275)	0.0 (275)	0.3 (748)	0.0 (748)	0.5 (723)	0.0 (723)
10	1.0 (384)	0.8 (384)	1.2 (172)	0.0 (172)	0.0 (300)	0.0 (300)	0.9 (889)	0.3 (889)	0.9 (856)	0.6 (856)
11	0.5 (369)	1.1 (369)	0.0 (188)	1.1 (188)	0.2 (418)	0.0 (418)	0.4 (1008)	0.7 (1008)	0.4 (975)	0.9 (975)
12	2.0 (397)	1.8 (397)	1.3 (159)	1.3 (159)	0.0 (470)	0.0 (470)	1.0 (1059)	0.8 (1059)	1.7 (1026)	1.5 (1026)
13	4.5 (354)	3.4 (354)	3.0 (66)	0.0 (66)	0.5 (214)	0.0 (214)	3.1 (648)	1.9 (648)	3.8 (634)	2.6 (634)
Adjusted Mean	**1.4 (2413)**	**1.1 (2413)**	**0.9 (931)**	**0.5 (931)**	**0.1 (2062)**	**0.0 (2062)**	**0.9 (5604)**	**0.6 (5604)**	**1.2 (5406)**	**0.9 (5406)**

Table XVI: Percentage of stunted and wasted black, mixed ancestry and white girls (6 to 13 years). Values are expressed as percentages and sample size (n).

Age (yrs)	Black		Mixed ancestry		White		All		Demographic Adjustment	
	WHO (2007)	CDC/WHO (1978)	WHO (2007)	CDC/WHO (1978)	WHO (2007)	CDC/WHO (1978)	WHO (2007)	CDC/WHO (1978)	WHO (2007)	CDC/WHO (1978)
6	1.0 (102)	1.0 (102)	0.0 (57)	0.0 (57)	0.0 (51)	0.0 (51)	0.5 (220)	0.5 (220)	0.8 (210)	0.8 (210)
7	0.4 (251)	0.4 (251)	0.0 (92)	0.0 (92)	0.0 (143)	0.0 (143)	0.2 (500)	0.2 (500)	0.3 (486)	0.3 (486)
8	1.0 (297)	0.3 (297)	0.0 (75)	0.0 (75)	0.0 (199)	0.0 (199)	0.5 (590)	0.2 (590)	0.8 (571)	0.2 (571)
9	0.7 (290)	0.0 (290)	0.0 (128)	0.0 (128)	0.0 (219)	0.0 (219)	0.3 (647)	0.0 (647)	0.5 (637)	0.0 (637)
10	0.6 (360)	0.3 (360)	0.0 (132)	0.0 (132)	0.0 (205)	0.0 (205)	0.4 (726)	0.3 (726)	0.5 (697)	0.2 (697)
11	0.8 (389)	0.8 (389)	2.9 (175)	0.6 (175)	0.0 (175)	0.0 (175)	1.1 (757)	0.5 (757)	0.9 (739)	0.7 (739)
12	0.5 (404)	0.0 (404)	1.2 (173)	1.7 (173)	0.6 (180)	0.6 (180)	0.6 (779)	0.5 (779)	0.5 (757)	0.2 (757)
13	0.9 (330)	0.6 (330)	0.0 (48)	0.0 (48)	0.0 (76)	0.0 (76)	0.6 (462)	0.4 (462)	0.7 (454)	0.5 (454)
Adjusted Mean	**0.7 (2423)**	**0.4 (2423)**	**0.8 (880)**	**0.5 (880)**	**0.1 (1248)**	**0.1 (1248)**	**0.5 (4681)**	**0.3 (4681)**	**0.6 (4551)**	**0.4 (4551)**

Table XVII: Percentage of underweight (weight-for-age < -2 z-score) black, mixed ancestry and white boys (6 to 13 years). Values are expressed as percentages and sample size (n).

	Black		Mixed ancestry		White		All		Demographic Adjustment	
Age (yrs)	**WHO (2007)**	**CDC/WHO (1978)**	**WHO (2007)**	**CDC/WHO (1978)**	**WHO (2007)**	**CDC/WHO (1978)**	**WHO (2007)**	**CDC/WHO (1978)**	**WHO (2007)**	**CDC/WHO (1978)**
6	2.1 (97)	2.1 (97)	7.1 (42)	7.1 (42)	2.0 (51)	2.0 (51)	4.0 (202)	4.0 (202)	2.4 (190)	2.4 (190)
7	9.4 (223)	3.6 (223)	7.1 (70)	4.3 (70)	0.0 (134)	0.0 (134)	7.2 (447)	3.4 (447)	7.9 (427)	3.1 (427)
8	6.7 (297)	2.4 (297)	3.7 (82)	2.4 (82)	1.0 (200)	0.5 (200)	4.3 (607)	1.8 (607)	5.6 (579)	2.1 (579)
9	12.9 (295)	2.0 (295)	9.8 (153)	2.0 (153)	2.2 (275)	0.0 (275)	8.0 (748)	1.2 (748)	11.0 (723)	1.7 (723)
Adjusted Mean	**8.9 (912)**	**2.5 (912)**	**7.5 (347)**	**3.2 (347)**	**1.4 (660)**	**0.3 (660)**	**6.3 (2004)**	**2.2 (2004)**	**7.6 (1919)**	**2.2 (1919)**

Table XVIII: Percentage of underweight (weight-for-age < -2 z-score) black, mixed ancestry and white girls (6 to 13 years). Values are expressed as percentages and sample size (n).

	Black		Mixed ancestry		White		All		Demographic Adjustment	
Age (yrs)	**WHO (2007)**	**CDC/WHO (1978)**	**WHO (2007)**	**CDC/WHO (1978)**	**WHO (2007)**	**CDC/WHO (1978)**	**WHO (2007)**	**CDC/WHO (1978)**	**WHO (2007)**	**CDC/WHO (1978)**
6	2.9 (103)	1.9 (103)	8.8 (57)	8.8 (57)	2.0 (51)	2.0 (51)	4.1 (221)	3.6 (221)	3.2 (211)	2.4 (211)
7	2.8 (251)	1.2 (251)	6.5 (93)	4.3 (93)	2.1 (143)	0.7 (143)	3.4 (501)	1.8 (501)	2.9 (487)	1.4 (487)
8`	6.4 (297)	1.7 (297)	5.3 (75)	0.0 (75)	2.5 (199)	0.5 (199)	5.1 (590)	1.0 (590)	5.6 (571)	1.4 (571)
9	8.6 (290)	2.1 (290)	7.0 (128)	0.8 (128)	0.9 (219)	0.5 (219)	5.7 (647)	1.2 (647)	7.3 (637)	1.7 (637)
Adjusted Mean	**5.7 (941)**	**1.7 (941)**	**6.8 (353)**	**2.8 (353)**	**1.8 (612)**	**0.7 (612)**	**4.8 (1959)**	**1.6 (1959)**	**5.1 (1906)**	**1.6 (1906)**

According to the WHO 2007 (6) norms, the prevalence of mild stunting among mixed ancestry children was twice that of white children. Black children showed triple the prevalence of moderate stunting when compared to the white children. The 1978 CDC/WHO (7) dataset, classified a smaller percentage of each sub-group as mildly stunted, however greater disparities between the white and other two ethnic groups were evident when compared to the WHO 2007 (6) classifications (Table IX and Table X).

Moderate stunting prevalence in black children was approximately double that noted among children of mixed ancestry. Moderate stunting among white children was considerably less at approximately one-twelfth of that in black children (WHO 2007 norms (6)). The 1978 CDC/WHO (7) dataset gave an overall lower moderate stunting prevalence among all groups in the sample, although proportional differences remained similar (Table XI and Table XII).

Table XIII and Table XIV indicate the prevalence of wasting among the boys and girls in this study. Black boys displayed levels of wasting approximately two-thirds that of mixed ancestry children, whereas white boys had a prevalence of wasting approximately half that of the mixed ancestry boys (WHO 2007 norms (6)). This trend was slightly different among the girls. White girls had a prevalence of wasting two-thirds that of mixed ancestry children and black children had a wasting prevalence one-half that of mixed ancestry children. These values were slightly elevated according to the 1978 CDC/WHO (7) dataset.

The co-prevalence of stunting and wasting is indicated in Table XV (boys) and Table XVI (girls). The prevalence of this condition was low among all ethnic and gender groups, however white children consistently had the lowest co-prevalence rates.

Underweight levels were similar between the black and mixed ancestry children. White girls showed an underweight prevalence one-third that of the other two ethnic groups, and white boys had an underweight prevalence of approximately one-sixth of the black and mixed ancestry children (Table XVII and Table XVIII). Although the 1978 CDC/WHO (7) dataset showed lower prevalence levels than the WHO 2007 (6) dataset, the proportional differences between the ethnic groups were similar.

Odds ratios of the nutritional anthropometric variables according to gender and ethnic group are presented in Table XXI. These are based on the demographically adjusted South African normative data. Few differences were evident between the ethnic groups. White boys showed significantly lower levels of both mild and moderate stunting for both the 1978 CDC/WHO (7) and WHO norms (6). According to the WHO 2007 norms (6) they were also less likely to be underweight. White girls had significantly lower odds of being mildly stunted according to both sets of normative data, and were less likely to be moderately stunted according to the WHO 2007 (6) normative data.

Table XIX and Table XX give the percentage of children falling above the cut-off points indicated by Cole et al. (13) for overweight and obesity. Since these values are classified as the percentage above the given cut-off points, the overweight cut-off includes both those children who are overweight and those who are obese. The data for the United States was calculated from information comparing different methods of overweight and obesity classification using the NHANES database (89). This paper presented data for age and gender categories using the classification method of Cole et al. (13) and hence the mean values used in the present study were calculated from these tables. The South African data has been changed into the format of the international data by using the cut-off point for overweight, without removing the obese subjects, hence explaining the discrepancy between the data in Table XIX and Table XX; and Table XXII.

Table XIX: Percentage of black, mixed ancestry and white boys (6 to 13 years) classified as overweight (25 kg.m^{-2} at 18 years) and obese (30 kg.m^{-2} at 18 years) according to curves developed by Cole et al. (13). Values are expressed as percentage (%) and sample size (n).

	Overweight					Obese				
Age (yrs)	**Black**	**Mixed**	**White**	**All**	**Demographic Adjustment**	**Black**	**Mixed**	**White**	**All**	**Demographic Adjustment**
6	5.3 (94)	4.8 (42)	17.6 (51)	8.0 (200)	6.1 (187)	4.3 (94)	2.4 (42)	9.8 (51)	6.0 (200)	4.4 (187)
7	4.9 (223)	7.2 (69)	17.9 (134)	9.2 (445)	6.1 (426)	1.8 (223)	2.9 (69)	3.0 (134)	2.5 (445)	1.9 (426)
8	7.1 (297)	6.1 (82)	15.5 (200)	9.7 (607)	7.4 (579)	2.0 (297)	1.2 (82)	3.5 (200)	2.6 (607)	2.0 (579)
9	4.7 (295)	9.2 (153)	10.5 (275)	7.9 (748)	5.4 (723)	0.7 (295)	3.9 (153)	3.6 (275)	2.7 (748)	1.2 (723)
10	8.3 (384)	10.5 (172)	15.0 (300)	11.7 (889)	8.7 (856)	2.9 (384)	4.1 (172)	6.0 (300)	4.3 (889)	3,2 (856)
11	6.8 (368)	9.6 (188)	17.2 (418)	11.7 (1007)	7.7 (974)	1.9 (368)	4.3 (188)	4.8 (418)	3.8 (1007)	2.3 (974)
12	11.4 (396)	9.4 (159)	15.3 (470)	12.9 (1058)	11.0 (1025)	1.8 (396)	1.3 (159)	3.2 (470)	2.6 (1058)	1.8 (1025)
13	8.8 (354)	6.1 (66)	16.4 (214)	10.8 (649)	8.8 (634)	2.3 (354)	1.5 (66)	4.2 (214)	2.8 (649)	2.3 (634)
Adjusted Mean	**7.6 (2411)**	**8.7 (931)**	**15.4 (2062)**	**10.8 (5603)**	**8.5 (5404)**	**2.1 (2411)**	**3.0 (931)**	**4.3 (2062)**	**3.2 (5603)**	**2.4 (5404)**

Table XX: Percentage of black, mixed ancestry and white girls (6 to 13 years) classified as overweight (25 kg.m^{-2} at 18 years) and obese (30 kg.m^{-2} at 18 years) according to curves developed by Cole et al. (13). Values are expressed as percentage (%) and sample size (n).

	Overweight					Obese				
Age (yrs)	**Black**	**Mixed**	**White**	**All**	**Demographic Adjustment**	**Black**	**Mixed**	**White**	**All**	**Demographic Adjustment**
6	9.9 (101)	10.5 (57)	17.6 (51)	11.9 (219)	10.2 (209)	2.0 (101)	5.3 (57)	7.8 (51)	4.1 (219)	2.7 (209)
7	8.8 (251)	12.0 (92)	17.5 (143)	11.8 (500)	9.5 (486)	4.0 (251)	7.6 (92)	7.7 (143)	5.8 (500)	4.5 (486)
8	14.1 (297)	8.0 (75)	12.6 (199)	12.9 (590)	12.7 (571)	3.4 (297)	6.7 (75)	7.5 (199)	5.4 (590)	3.9 (571)
9	9.7 (290)	11.7 (128)	16.0 (219)	12.1 (647)	10.0 (637)	4.5 (290)	2.3 (128)	4.6 (219)	4.0 (647)	4.1 (637)
10	13.6 (360)	9.8 (132)	18.0 (205)	14.0 (726)	13.0 (697)	5.3 (360)	6.1 (132)	5.9 (205)	5.4 (726)	5.2 (697)
11	12.6 (389)	14.3 (175)	17.7 (175)	14.3 (757)	12.6 (739)	4.4 (389)	5.1 (175)	4.6 (175)	4.6 (757)	4.3 (739)
12	12.6 (404)	9.2 (173)	11.7 (180)	12.7 (779)	11.6 (757)	4.0 (404)	4.0 (173)	5.0 (180)	4.2 (779)	3.9 (757)
13	14.2 (330)	4.2 (48)	13.2 (76)	12.8 (462)	12.5 (454)	7.6 (330)	0.0 (48)	1.3 (76)	5.8 (462)	6.0 (454)
Adjusted Mean	**12.3 (2422)**	**10.7 (880)**	**15.5 (1248)**	**13.0 (4680)**	**12.7 (4550)**	**4.7 (2422)**	**4.8 (880)**	**7.8 (1248)**	**4.9 (4680)**	**4.8 (4680)**

Table XXI: Odds ratios of the nutritional anthropometry of the different ethnic groups according to the National, South African, demographically adjusted nutritional anthropometric prevalence rates for each variable.

	Black		Mixed		White	
	OR	CI	OR	CI	OR	CI
WHO (2007), Boys						
Mild Stunting	1.25	0.69 – 2.30	0.72	0.38 – 1.36	0.26	0.12 – 0.56 §
Moderate Stunting	1.32	0.59 – 2.94	0.45	0.17 – 1.22	0.10	0.02 – 0.43 §
Wasting	1.03	0.31 – 3.43	1.58	0.53 – 4.76	0.78	0.22 – 2.82
Stunting and Wasting	1.20	0.10 – 14.23	0.77	0.05 – 12.12	0.08	0.00 – 13.75
Underweight	1.18	0.43 – 3.24	0.98	0.34 – 2.80	0.17	0.03 – 0.87 §
WHO (2007), Girls						
Mild Stunting	1.26	0.68 – 2.34	0.60	0.30 – 1.18	0.28	0.13 – 0.61 §
Moderate Stunting	1.25	0.52 – 3.05	0.54	0.19 – 1.56	0.08	0.01 – 0.47 §
Wasting	0.89	0.20 – 4.05	2.18	0.63 – 7.61	1.38	0.35 – 5.43
Stunting and Wasting	1.13	0.04 – 35.01	1.30	0.05 – 35.94	0.16	0.00 – 55.66
Underweight	1.11	0.33 – 3.79	1.34	0.41 – 4.36	0.34	0.07 – 1.75
CDC/WHO *(1978), Boys*						
Mild Stunting	1.26	0.65 – 2.45	0.68	0.33 – 1.42	0.14	0.05 – 0.40 §
Moderate Stunting	1.28	0.43 – 3.79	0.29	0.06 – 1.39	0.08	0.01 – 0.72 §
Wasting	1.04	0.36 – 3.02	1.49	0.55 – 4.02	0.81	0.26 – 2.51
Stunting and Wasting	1.24	0.08 – 20.40	0.56	0.02 – 17.22	0.00	0.00 – 0.00 §
Underweight	1.12	0.18 – 6.97	1.45	0.26 – 8.12	0.13	0.01 – 3.40
CDC/WHO *(1978), Girls*						
Mild Stunting	1.27	0.62 – 2.57	0.53	0.23 – 1.22	0.15	0.05 – 0.45 §
Moderate Stunting	1.24	0.35 – 4.42	0.47	0.10 – 2.34	0.11	0.01 –1.18
Wasting	0.90	0.22 – 3.63	2.24	0.71 – 7.09	1.31	0.36 – 4.73
Stunting and Wasting	1.11	0.01 – 100.48	1.39	0.02 – 99.38	0.28	0.00 – 193.60
Underweight	1.05	0.12 – 9.22	1.75	0.25 – 12.09	0.43	0.03 – 6.62
IOTF (2000), Boys						
Overweight	0.94	0.33 – 2.64	1.09	0.40 – 2.96	2.08	0.86 – 5.05
Obese	0.92	0.14 – 6.11	1.33	0.23 – 7.55	1.93	0.39 – 9.57
IOTF (2000), Girls						
Overweight	1.04	0.45 – 2.44	0.89	0.37 – 2.14	1.36	0.61 – 3.07
Obese	0.99	0.27 – 3.63	1.01	0.27 – 3.69	1.69	0.53 – 5.40

Note: Significant odds ratios are marked with §.

Table XXII: Percentage of children in different countries, above the cut-off points for overweight and obesity. Values taken from curves created to pass through body mass index of 25 and 30 $kg.m^{-2}$ at age 18 (Adapted from (13); (91); (89); (468); (470); (102)). The percentage above $25kg.m^{-2}$ at age 18 gives an indication of overweight and obesity prevalence combined.

Country and year	Percent above cut off point for overweight		Percent above cut off point for obese	
	Males	Females	Males	Females
United States (1976-1980)	14.9	15.1	3.4	4.3
Netherlands (1980)	5.5	6.5	0.3	0.3
Brazil (1989)	4.7	15.2	0.1	2.0
Hong Kong (1993)	11.7	9.8	3.1	1.8
Singapore (1993)	10.5	7.0	1.7	1.0
England (1994)	9.0	13.5	1.7	2.6
Scotland (1994)	10.0	15.8	2.1	3.2
United States (1988-1994)	22.1	24.0	7.0	8.2
Turkey (2001-2002)	14.9	12.9	1.7	2.3
Greece (1997-1998)	23.7	11.7	2.4	1.1
South Africa (SA) (2001-2004)	14.0	17.9	3.2	4.9
Black SA (2001-2004)	9.7	17.0	2.1	4.7
Mixed ancestry SA (2001-2004)	11.7	15.5	3.0	4.8
White SA (2001-2004)	19.7	21.1	4.3	5.6
SA Demographic Adjustment	10.9	17.5	2.4	4.8

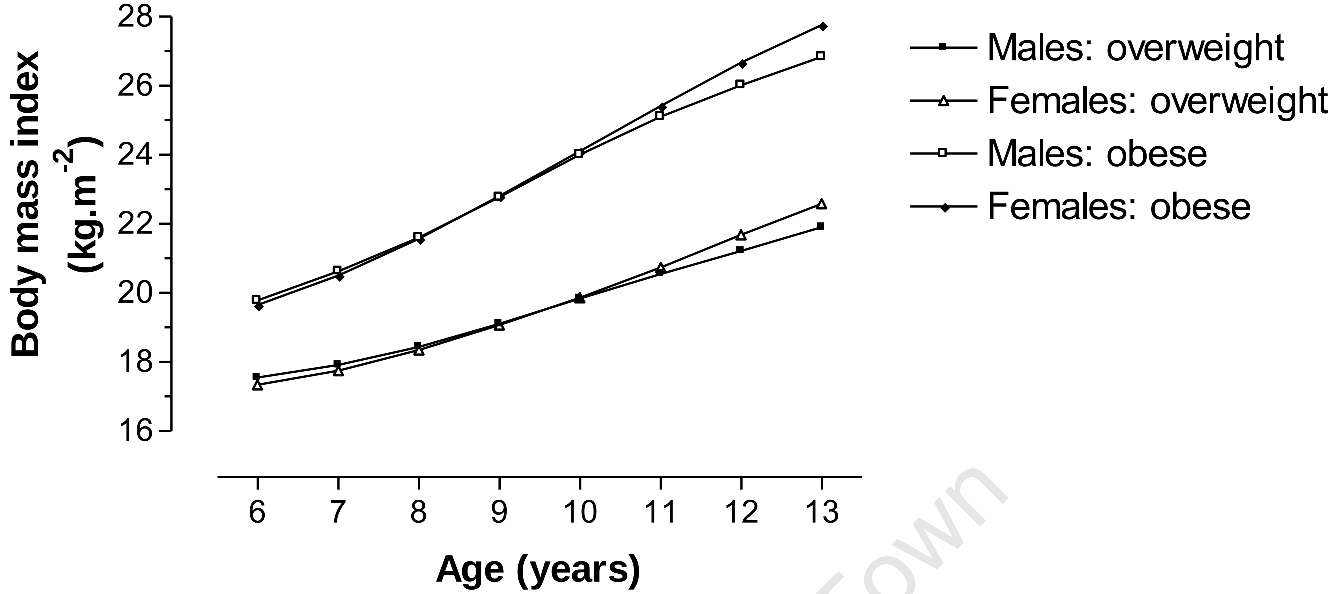

Figure 10: Cut-off points for gender and age (6 to 13 years) for body mass index predicted to classify subjects as overweight (BMI of 25 kg.m^{-2}) and obese (BMI of 30 kg.m^{-2}) at 18 years (adapted from (13)).

Figure 10 is adapted from the data of Cole et al. (13) and displays the international BMI cut-off points for predicted overweight and obesity at 18 years for the age groups 6 through 13 years.

4.3 Part 2: Physical Fitness Study

To date, the physical fitness levels of a large, diverse group of young South Africans have not been assessed. Therefore, this section considered the physical fitness performance of South African Primary school children on the sit-and-reach, standing long jump, sit-up, 5-metre shuttle run and cricket ball throw tests. The scores of boys and girls were considered separately with results reported according to ethnic group and the full sample.

4.3.1 **Sit-and-reach**

The sit-and-reach scores, and by implication flexibility, changed significantly with age in the boys (F = 3.3; P < 0.001854) and girls (F = 2.8; P < 0.006804). These differences were small and unlikely to have been meaningful. There was a significant interaction between age and ethnicity in both the boys (F = 5.3; P < 0.0000001) and girls (F = 4.2; P < 0.0000001). In most instances, sit-and-reach scores of the boys declined with age, except for the white boys, whose scores improved from age 6 to 8, and declined again in 12 year olds. While the black girls had similar scores across age groups, the white girls showed a general improvement until 10 years. The mixed ancestry children increased their flexibility until 8 years, declined until 10 years and then again showed improvements until 13 years. Significant differences in sit-and-reach scores were evident between ethnicities in both the boys (F = 15.4; P < 0.0000001) and the girls (F = 47.5; P < 0.0000001), except between the black and white boys (Table XXIII).

4.3.2 **Standing long jump**

The distance the children jumped increased significantly until age 13 in both boys (F = 453.2; P < 0.0000001) and girls (F = 342.6; P < 0.0000001). The standing long jump scores of the different ethnic groups changed at different rates with age in the boys (F = 3.8; P < 0.000002) and girls (F = 3.2; P < 0.000041). This was most evident in the mixed ancestry children who displayed similar scores to the black children in the younger age groups but jumped similar distances to the white children in the older age groups. Standing long jump scores of the children were significantly different between ethnic groups (Boys: F = 445.5; P < 0.0000001 and Girls: (F = 355.7; P < 0.0000001) with the black children jumping the shortest distance. The white children jumped the furthest distance in most cases (Table XXIII).

4.3.3 **Sit-ups**

The number of sit-ups performed increased significantly up until 11 years of age in both the boys ($F = 184.7$; $P < 0.0000001$) and girls ($F = 111.0$; $P < 0.0000001$). A significant interaction was evident between age and ethnicity in the sit-up test in the group of boys ($F = 2.7$; $P < 0.000513$) and girls ($F = 2.2$; $P < 0.005948$). Mixed ancestry boys and girls, performed a similar number of sit-ups to the black children within the younger categories but improved at a faster rate than the other groups, such that they scored similarly to the white children in the older groups. There was a significant difference in the number of sit-ups completed between ethnic groups in both boys ($F = 201.0$; $P < 0.0000001$) and girls ($F = 200.8$; $P < 0.0000001$) with the white children completing the most and the black children the least number of sit-ups in the majority of age groups (Table XXV).

4.3.4 **Shuttle run**

The shuttle run times of the boys decreased significantly (i.e. performance improved) with age until 12 years ($F = 154.4$; $P < 0.0000001$). The black children were consistently slower than the white children and children of mixed ancestry, when genders and all age groups over 6 years were compared. The rate of change of shuttle run times between ethnic groups with age was different in the boys ($F = 3.4$; $P < 0.000019$), but not the girls (non-significant interaction $F = 0.5$; $P < 0.943796$). There was, however, a significant decrease in shuttle run times in the girls until 9 years of age ($F = 103.4$; $P < 0.0000001$). The shuttle run times were different between the ethnic groups, except between the white and mixed ancestry groups of boys ($F = 282.9$; $P < 0.0000001$) and girls ($F = 271.6$; $P < 0.0000001$) (Table XXVI).

4.3.5 **Cricket ball throw**

The cricket ball throwing distance increased significantly with increasing age in all groups ($P < 0.0000001$), however, there was a significant interaction effect between age and ethnicity for both boys ($P < 0.000002$) and girls ($P < 0.0000001$). There was a significant difference in distance thrown between ethnic groups in the boys ($F = 180.8$; $P < 0.0000001$) and girls ($F = 110.8$; $P < 0.0000001$). Initially the mixed ancestry boys threw the furthest but at the age of 10 years, the white boys started to throw the furthest while the black boys threw the shortest distance. An opposite pattern was evident among the girls, with the black girls throwing the furthest and the white girls the shortest distance (Table XXVII).

ANCOVAs co-varying for height, body weight and BMI did not significantly alter the differences observed between the different ethnic groups on all of the physical fitness tests.

Table XXIII: Sit-and-reach scores (cm) of black, mixed ancestry and white children (6 to 13 years). Values are expressed as means ± SD and sample size (n).

Age (yrs)	Boys				Girls			
	Black	Mixed ancestry	White	All	Black	Mixed ancestry	White	All
6	22.1 ± 6.8 (97)	24.3 ± 6.6 (42)	18.8 ± 7.3 (49)	21.4 ± 7.2 (201)	23.0 ± 6.6 (103)	22.9 ± 9.3 (57)	25.7 ± 7.2 (51)	23.2 ± 7.8 (221)
7	22.3 ± 6.3 (223)	21.9 ± 7.2 (70)	19.9 ± 7.6 (133)	21.3 ± 6.9 (446)	24.1 ± 6.4 (251)	21.2 ± 8.6 (93)	25.7 ± 8.0 (143)	23.8 ± 7.5 (501)
8	22.9 ± 6.6 (296)	21.4 ± 8.8 (82)	21.2 ± 7.6 (200)	21.8 ± 7.4 (606)	23.6 ± 6.1 (297)^{w}	24.6 ± 6.8 (75)	27.8 ± 6.7 (198)^{b}	25.0 ± 6.8 (589)
9	22.2 ± 6.0 (295)	22.8 ± 7.4 (153)	20.8 ± 8.4 (276)	21.6 ± 7.4 (749)	23.0 ± 5.8 (290)	24.9 ± 6.6 (128)	26.4 ± 7.4 (219)	24.4 ± 6.8 (647)
10	21.3 ± 6.1 (384)	22.9 ± 7.5 (171)	21.4 ± 8.0 (298)	21.5 ± 7.2 (886)	22.9 ± 5.8 (358)	26.2 ± 6.3 (132)	24.7 ± 8.0 (205)	23.8 ± 6.9 (724)
11	20.4 ± 5.4 (368)	23.2 ± 8.4 (186)	22.5 ± 7.9 (413)	21.6 ± 7.3 (1000)	22.8 ± 5.8 (388)	25.9 ± 8.3 (174)	26.1 ± 7.7 (175)	24.2 ± 7.1 (755)
12	19.1 ± 6.1 (396)	22.6 ± 8.0 (158)	21.0 ± 8.3 (465)	20.3 ± 7.6 (1052)	23.2 ± 6.8 (404)	25.6 ± 8.4 (173)	25.4 ± 10.1 (180)	24.1 ± 8.2 (779)
13	20.5 ± 6.5 (354)	21.2 ± 7.4 (66)	19.8 ± 8.8 (207)	20.2 ± 7.5 (642)	24.6 ± 7.4 (331)	25.2 ± 9.2 (48)	27.0 ± 8.7 (76)	25.0 ± 7.8 (463)
Adjusted Mean	**21.1 (2413)**	**22.6 (928)**	**21.1 (2041)**	**21.2 (5582)**	**23.4 (2422)**	**24.9 (880)**	**26.1 (1247)**	**24.2 (4679)**

Table XXIV: Standing long jump scores (cm) of black, mixed ancestry and white children (6 to 13 years). Values are expressed as means ± SD and sample size (n).

Age (yrs)	Boys				Girls			
	Black	Mixed ancestry	White	All	Black	Mixed ancestry	White	All
6	113.7 ± 18.9 (95)	116.0 ± 24.8 (42)	128.6 ± 19.8 (51)	117.4 ± 22.4 (201)	105.4 ± 21.0 (103)^{w}	117.4 ± 21.8 (56)	128.0 ± 17.1 (51)^{b}	112.5 ± 23.4 (220)
7	121.8 ± 20.2 (221)^{w}	133.4 ± 22.0 (70)	143.4 ± 18.0 (134)^{b}	130.2 ± 22.2 (445)	115.8 ± 18.5 (251)^{w}	119.5 ± 22.4 (92)	134.9 ± 17.7 (142)^{b}	121.7 ± 21.0 (499)
8	134.6 ± 19.5 (294)$^{m\ w}$	151.0 ± 18.3 (82)^{b}	160.0 ± 18.1 (200)^{b}	145.3 ± 22.1 (604)	126.0 ± 20.1 (292)$^{m\ w}$	144.1 ± 23.0 (74)^{b}	149.0 ± 21.8 (199)^{b}	135.9 ± 24.0 (584)
9	144.6 ± 23.4 (294)$^{m\ w}$	162.2 ± 23.7 (153)^{b}	167.8 ± 19.2 (276)^{b}	156.8 ± 24.2 (748)	135.1 ± 20.3 (289)^{w}	148.2 ± 26.9 (128)	155.7 ± 19.9 (219)^{b}	144.6 ± 23.5 (646)
10	156.2 ± 21.6 (380)$^{m\ w}$	174.1 ± 20.3 (171)^{b}	174.0 ± 21.1 (300)^{b}	165.7 ± 22.9 (884)	144.8 ± 19.1 (354)$^{m\ w}$	165.0 ± 22.7 (132)^{b}	161.7 ± 20.7 (205)^{b}	153.3 ± 22.3 (720)
11	160.9 ± 18.8 (368)$^{m\ w}$	182.9 ± 23.6 (188)^{b}	182.8 ± 22.4 (420)^{b}	174.1 ± 24.0 (1009)	152.4 ± 19.5 (388)$^{m\ w}$	169.6 ± 21.0 (175)^{b}	171.8 ± 19.3 (175)^{b}	161.0 ± 21.7 (756)
12	166.5 ± 20.5 (395)$^{m\ w}$	191.7 ± 23.7 (159)^{b}	189.1 ± 21.4 (469)^{b}	180.2 ± 24.3 (1056)	157.5 ± 21.8 (404)$^{m\ w}$	170.2 ± 25.3 (173)^{b}	178.8 ± 22.8 (177)^{b}	165.4 ± 24.5 (775)
13	174.1 ± 21.9 (348)$^{m\ w}$	194.2 ± 21.2 (66)^{b}	197.5 ± 22.9 (211)^{b}	184.1 ± 24.9 (640)	161.1 ± 22.1 (328)^{w}	176.0 ± 27.7 (48)	185.6 ± 24.3 (76)^{b}	166.8 ± 24.9 (460)
Adjusted Mean	**152.3 (2395)**	**172.1 (793)**	**176.3 (2061)**	**164.1 (5587)**	**142.2 (2409)**	**155.5 (878)**	**159.5 (1244)**	**149.2 (4660)**

Table XXV: Sit-up scores (number completed in 30s) of black, mixed ancestry and white children (6 to 13 years). Values are expressed as means ± SD and sample size (n).

Age (yrs)	Boys				Girls			
	Black	Mixed ancestry	White	All	Black	Mixed ancestry	White	All
6	9.1 ± 5.2 (97)	9.3 ± 5.4 (42)	14.0 ± 5.7 (51)	10.4 ± 5.8 (203)	6.5 ± 5.1 (103)	7.9 ± 4.2 (57)	10.2 ± 4.3 (51)	7.7 ± 4.9 (221)
7	11.1 ± 5.1 (223) [w]	12.6 ± 4.6 (71)	15.2 ± 4.8 (133) [b]	12.6 ± 5.3 (447)	7.9 ± 5.4 (251) [w]	9.7 ± 5.5 (93)	12.4 ± 4.4 (143) [b]	9.5 ± 5.5 (501)
8	13.6 ± 5.1 (293) [w]	16.0 ± 5.6 (82)	18.1 ± 4.1 (200) [b]	15.6 ± 5.3 (603)	10.4 ± 5.1 (297) [w]	13.3 ± 6.0 (75)	13.9 ± 4.7 (199) [b]	11.8 ± 5.4 (590)
9	15.4 ± 5.4 (295) [w]	18.1 ± 5.0 (153)	18.7 ± 5.1 (276) [b]	17.3 ± 5.4 (749)	11.1 ± 5.3 (290) [m w]	14.7 ± 5.4 (128) [b]	16.2 ± 4.9 (219) [b]	13.5 ± 5.7 (647)
10	17.3 ± 5.3 (383) [w]	19.4 ± 5.1 (172)	19.8 ± 4.4 (302) [b]	18.5 ± 5.1 (890)	13.4 ± 5.5 (362) [m]	16.5 ± 5.3 (132) [b]	16.0 ± 4.7 (204)	14.6 ± 5.4 (727)
11	18.2 ± 5.2 (369) [w]	20.3 ± 5.4 (187)	20.9 ± 4.4 (418) [b]	19.7 ± 5.1 (1007)	13.8 ± 5.5 (389) [w]	16.4 ± 5.1 (175)	17.3 ± 3.8 (175) [b]	15.2 ± 5.3 (757)
12	18.8 ± 4.8 (397) [w]	21.3 ± 4.7 (159)	21.7 ± 4.2 (470) [b]	20.4 ± 4.8 (1059)	13.9 ± 5.9 (404) [w]	16.2 ± 5.7 (173)	17.2 ± 4.7 (179) [b]	15.1 ± 5.7 (778)
13	18.9 ± 5.0 (354) [w]	21.6 ± 5.0 (66)	21.7 ± 4.7 (212) [b]	20.1 ± 5.1 (647)	13.8 ± 4.6 (331) [w]	17.5 ± 4.3 (48)	17.7 ± 3.5 (75) [b]	14.8 ± 4.7 (462)
Adjusted Mean	**16.3 (2411)**	**18.6 (932)**	**19.9 (2062)**	**18.0 (5605)**	**12.1 (2427)**	**14.7 (881)**	**15.5 (1245)**	**13.4 (4683)**

Table XXVI: Shuttle run scores (s) of black, mixed ancestry and white children (6 to 13 years). Values are expressed as means ± SD and sample size (n).

Age (yrs)	Boys				Girls			
	Black	Mixed ancestry	White	All	Black	Mixed ancestry	White	All
6	25.5 ± 3.1 (96)	24.2 ± 2.5 (42)	23.9 ± 2.0 (51)	24.9 ± 3.0 (201)	25.9 ± 3.6 (102)	24.6 ± 2.4 (57)	24.5 ± 2.0 (51)	25.4 ± 3.1 (219)
7	24.7 ± 2.9 (216) [w]	23.2 ± 2.1 (71)	23.2 ± 2.1 (133) [b]	24.1 ± 2.6 (440)	25.2 ± 3.1 (248) [w]	24.0 ± 2.3 (92)	23.7 ± 1.5 (142) [b]	24.6 ± 2.7 (496)
8	23.9 ± 2.5 (290) [m w]	22.1 ± 1.5 (81) [b]	22.1 ± 1.4 (199) [b]	23.1 ± 2.2 (598)	24.6 ± 2.8 (294) [m w]	22.7 ± 1.5 (75) [b]	23.1 ± 1.4 (198) [b]	23.9 ± 2.4 (585)
9	23.1 ± 2.1 (293) [m w]	21.6 ± 1.4 (152) [b]	21.9 ± 1.4 (276) [b]	22.4 ± 1.8 (746)	23.9 ± 2.3 (289) [m w]	22.3 ± 1.5 (128) [b]	22.5 ± 1.4 (218) [b]	23.1 ± 2.1 (645)
10	22.7 ± 1.9 (382) [m w]	21.4 ± 1.4 (172) [b]	21.3 ± 1.3 (301) [b]	22.0 ± 1.8 (888)	23.6 ± 2.2 (362) [m w]	22.1 ± 1.5 (132) [b]	21.9 ± 1.3 (205) [b]	22.9 ± 2.0 (728)
11	22.6 ± 2.4 (368) [m w]	21.3 ± 1.3 (188) [b]	20.9 ± 1.3 (420) [b]	21.6 ± 2.0 (1009)	23.3 ± 2.1 (389) [m w]	21.6 ± 1.2 (174) [b]	21.6 ± 1.2 (175) [b]	22.5 ± 1.9 (756)
12	21.8 ± 1.9 (396) [m w]	20.5 ± 1.6 (159) [b]	20.7 ± 1.3 (470) [b]	21.1 ± 1.7 (1058)	23.0 ± 2.3 (403) [m w]	21.4 ± 1.6 (172) [b]	21.4 ± 1.2 (178) [b]	22.3 ± 2.1 (775)
13	21.6 ± 1.9 (353)	20.1 ± 1.6 (66)	20.9 ± 1.8 (213)	21.2 ± 1.9 (646)	22.9 ± 2.2 (330) [w]	21.1 ± 1.5 (47)	21.3 ± 1.2 (76) [b]	22.4 ± 2.2 (461)
Adjusted Mean	**22.9 (2394)**	**21.5 (931)**	**21.4 (2063)**	**22.1 (5586)**	**23.8 (2417)**	**22.3 (877)**	**22.3 (1243)**	**23.1 (4665)**

Table XXVII: Cricket ball throw scores (m) of black, mixed ancestry and white children (6 to 13 years). Values are expressed as means ± SD and sample size (n).

Age (yrs)	Boys				Girls			
	Black	**Mixed ancestry**	**White**	**All**	**Black**	**Mixed ancestry**	**White**	**All**
6	11.8 ± 4.5 (97)	12.4 ± 4.2 (42)	12.8 ± 4.8 (51)	12.1 ± 4.6 (203)	8.2 ± 3.1 (103)	8.6 ± 3.1 (57)	7.2 ± 2.2 (50)	7.9 ± 3.0 (220)
7	12.8 ± 4.2 (223)	16.7 ± 6.0 (71)	16.4 ± 5.9 (134)	14.5 ± 5.4 (448)	9.6 ± 3.4 (250)	8.9 ± 2.9 (93)	8.6 ± 2.8 (143)	9.1 ± 3.2 (500)
8	16.3 ± 5.1 (288) [w]	20.6 ± 6.2 (82)	21.0 ± 6.5 (191) [b]	18.4 ± 6.2 (587)	12.4 ± 3.6 (294)	12.3 ± 4.4 (75)	10.1 ± 3.2 (199)	11.5 ± 3.8 (587)
9	19.3 ± 6.4 (292) [m w]	23.8 ± 6.7 (150) [b]	23.6 ± 6.8 (264) [b]	21.8 ± 7.0 (730)	14.1 ± 4.6 (290)	14.5 ± 6.1 (128)	12.7 ± 4.4 (219)	13.6 ± 4.9 (647)
10	23.9 ± 6.7 (380) [w]	27.3 ± 6.6 (172)	27.8 ± 7.6 (302) [b]	25.9 ± 7.2 (887)	18.0 ± 5.3 (356) [w]	16.0 ± 4.7 (132)	13.6 ± 3.7 (205) [b]	16.1 ± 5.1 (722)
11	26.0 ± 6.5 (365) [w]	29.0 ± 8.0 (188)	31.4 ± 8.6 (420) [b]	28.7 ± 8.1 (1006)	20.4 ± 5.1 (382) [w]	17.8 ± 5.6 (175)	16.3 ± 5.2 (175) [b]	18.7 ± 5.6 (750)
12	29.3 ± 6.7 (395) [m w]	35.1 ± 7.6 (157) [b]	36.2 ± 8.7 (470) [b]	33.1 ± 8.6 (1055)	22.6 ± 5.8 (402) [w]	20.3 ± 6.5 (168)	19.2 ± 6.6 (179) [b]	21.1 ± 6.3 (771)
13	32.5 ± 7.8 (350) [w]	37.0 ± 9.3 (64)	39.2 ± 10.0 (214) [b]	35.2 ± 9.4 (643)	24.8 ± 6.4 (331) [w m]	22.6 ± 7.1 (48) [b]	19.4 ± 7.1 (76) [b]	23.6 ± 6.9 (463)
Adjusted Mean	**23.4 (2390)**	**27.0 (926)**	**29.4 (2046)**	**26.1 (5559)**	**17.6 (2408)**	**15.8 (876)**	**13.6 (1246)**	**16.0 (4660)**

Table XXVIII: Health related fitness scores for South African boys and girls (6 to 13 years) in comparison to other countries. Values are expressed as the percentage difference from the South African data. In the case of the shuttle run, where a lower score is more favourable, the sign of the percentage difference has been reversed to ensure consistency. A '+' prior to a number indicates that children from that country performed better than South African children, whereas a '–' prior to a number indicates that they performed poorer than South African children Countries annotated by a star refer to those for which a full range of data, from 6 to 13 year olds, was not available.

BOYS

	Height	Weight	BMI	Sit-and-reach	Sit-ups	Shuttle run	Standing long jump
South Africa	0	0	0	0	0	0	0
Belgium	+3.0	+4.6	-1.9	-10.4	+16.4	-3.1	-6.2
Estonia *	+2.3	+6.4	+2.1	-25.2	+8.6	+0.1	-7.4
Iceland *	No data	No data	No data	-10.9	+7.2	+0.9	+5.1
Italy *	-4.4	No data	No data	-40.4	-11.8	+ 2.8	-12.9
Poland *	+3.6	+9.5	+2.1	No data	+20.6	No data	-8.6
Spain *	+1.8	+8.1	+4.8	-29.0	+1.9	+1.5	-11.1
Slovakia *	+4.0	+9.0	+0.8	-15.1	+26.9	+2.6	-3.0
Switzerland *	No data	No data	No data	+15.2	+28.4	+2.1	-5.5
Turkey *	-0.8	-2.3	-0.8	+10.9	-3.5	+7.1	-6.6
Zaire	-8.6	-26.1	-11.2	+14.7	-36.8	+22.6	-22.2
RANGE	**12.6**	**35.6**	**16.0**	**55.6**	**65.2**	**25.7**	**27.3**

GIRLS

	Height	Weight	BMI	Sit-and-reach	Sit-ups	Shuttle run	Standing long jump
South Africa	0	0	0	0	0	0	0
Belgium	+2.9	+4.8	-1.7	-5.2	+39.2	-2.6	-4.0
Estonia *	+1.9	+1.0	-2.9	-9.6	+30.8	-0.5	-5.1
Iceland *	No data	No data	No data	+9.6	+21.8	+3.7	+11.2
Italy *	+3.1	No data	No data	-31.7	+10.2	+2.8	-21.4
Poland *	+3.1	+4.4	-1.6	No data	+44.1	No data	-7.3
Spain *	+2.6	+9.6	+4.4	-17.8	+13.3	+2.0	-12.1
Slovakia *	+4.0	+3.8	-3.5	-9.9	+56.9	+3.3	-0.9
Switzerland *	No data	No data	No data	+17.6	+54.1	+1.8	-3.7
Turkey *	-0.6	-6.5	-5.1	+3.2	+6.0	+7.2	-5.1
Zaire	-8.2	-25.7	-11.5	+5.6	-38.4	-8.6	-6.3
RANGE	**12.2**	**35.3**	**15.9**	**49.3**	**95.3**	**15.8**	**32.6**

Table XXVIII compared the average performance of the group of South African children to that of children from other countries, including samples from both developed and emerging nations. South African children showed higher scores in comparison to other African children for all the measurements except the flexibility of boys and girls, and the shuttle run performance of boys. The largest differences between European and South African children were in flexibility, sit-ups and standing long jump whereas shuttle run scores were similar between the different countries.

4.4 Part 3: Interactions Study

The interactions between the different variables measured in this dissertation were considered in this study, with the main focus placed on whether the nutritional status of children affected their physical fitness performance. To simplify the interpretation and standardise the different scales, the percentile values for the anthropometric and physical fitness variables were used in this analysis.

Table XXIX: Reliability and Item Analysis of physical fitness data of South African boys and girls (6 to 13 years).

	Initial Exploratory Analysis	
Variable	**Item total Correlation**	**Alpha if Deleted**
Standing Jump	+0.55	0.47
Shuttle Run	+0.44	0.53
Sit-ups	+0.36	0.57
Ball throw	+0.30	0.60
Sit-and-reach	+0.22	0.64

An exploratory analysis of the internal reliability of the physical fitness scores revealed a Cronbach's α of 0.62, and a standardised Cronbach's α of 0.62 with an average inter-item correlation of 0.25 (n=10082) (Table XXIX). As these values were low, compiling a combined fitness score would not have added to the overall interpretation of results. Therefore, further analysis considered each fitness variable separately.

The Pearson Product-Moment correlations (Table XXX) indicated significant correlations of the majority of variables at a confidence level of $p < 0.01$. The strongest correlations for variables not inherently linked were noted between socioeconomic status and the other variables, with the lowest correlations between the sit-and-reach test and other variables. The obesity index referred to those children classified as either obese or overweight according to the Cole classification (13).

The coefficients of determination (Table XXXI) showed that the percentage of variance in common between many of the variables was small. However, socioeconomic status showed higher coefficients of determination than nutritional indicators, with respect to the fitness test performances.

Table XXX: Pearson Product-Moment Correlation coefficients for boys and girls (n = 9781, p < 0.01).

	Socio	O/In	Stunt	Ht	Mass	BMI	BMI18	SJ	SR	SU	BT	SaR
Socio	1.00	+0.10§	+0.21§	+0.41§	+0.31§	+0.12§	+0.13§	+0.40§	+0.29§	+0.27§	+0.01	+0.06§
O/In		1.00	-0.06§	+0.19§	+0.58§	+0.65§	+0.75§	-0.13§	-0.09§	-0.12§	+0.00	-0.02
Stunt			1.00	-0.47§	-0.36§	-0.09§	-0.09§	-0.20§	-0.12§	-0.11§	-0.11§	-0.01
Ht				1.00	+0.71§	+0.25§	+0.24§	+0.34§	+0.19§	+0.18§	+0.16§	+0.01
Mass					1.00	+0.83§	+0.80§	+0.13§	+0.05§	+0.04§	+0.14§	+0.01
BMI						1.00	+0.93§	-0.08§	-0.08§	-0.08§	+0.08§	+0.00
BMI18							1.00	-0.12§	-0.10§	-0.12§	+0.05§	-0.01
SJ								1.00	+0.44§	+0.39§	+0.27§	+0.23§
SR									1.00	+0.27§	+0.23§	+0.15§
SU										1.00	+0.18§	+0.09§
BT											1.00	+0.09§
SaR												1.00

Note: Socio = Socioeconomic status, O/In = Obesity Index, Stunt = stunting, Ht = Height, BMI18 = predicted BMI at 18, SJ = Standing jump, SR = Shuttle run, SU = Sit-up, BT = Ball throw, SaR = Sit-and-reach. Significant correlations are marked with §.

Table XXXI: Coefficient of determination values for boys and girls (n = 9781).

	Socio	O/In	Stunt	Ht	Mass	BMI	BMI18	SJ	SR	SU	BT	SaR
Socio	1.00	+0.01	+0.04	+0.17	+0.10	+0.01	+0.02	+0.16	+0.08	+0.07	+0.00	+0.00
O/In		1.00	-0.00	+0.04	+0.34	+0.42	+0.56	-0.02	-0.01	-0.01	+0.00	-0.00
Stunt			1.00	-0.22	-0.13	-0.01	-0.01	-0.04	-0.01	-0.01	-0.01	-0.00
Ht				1.00	+0.50	+0.06	+0.06	+0.12	+0.04	+0.03	+0.03	+0.00
Mass					1.00	+0.69	+0.64	+0.02	+0.00	+0.00	+0.02	+0.00
BMI						1.00	+0.86	-0.01	-0.01	-0.01	+0.01	+0.00
BMI18							1.00	-0.01	-0.01	-0.01	+0.00	-0.00
SJ								1.00	+0.19	+0.15	+0.07	+0.05
SR									1.00	+0.07	+0.05	+0.02
SU										1.00	+0.03	+0.01
BT											1.00	+0.01
SaR												1.00

Note: Socio = Socioeconomic status, O/In = Obesity Index, Stunt = stunting, Ht = Height, BMI18 = predicted BMI at 18, SJ = Standing jump, SR = Shuttle run, SU = Sit-up, BT = Ball throw, SaR = Sit-and-reach

To allow for standardised comparisons, the percentile physical fitness test scores were used to compare the physical fitness of children classified as nutritionally deficient or over-nourished to that of healthy children. Gender, age, ethnicity and socioeconomic group were used as co-variates. The adjusted and unadjusted means and standard deviations may be viewed in Appendix F: Interactions Study Tables.

Overweight or obese children performed significantly poorer than those children not classified as overweight or obese on all tests except the ball throw test, for which there was no difference between the groups (Sit-and-reach: $p < 0.001259$; Standing jump: $p < 0.0000001$; Sit-ups: $p < 0.0000001$; Shuttle run: $p < 0.0000001$; Ball throw: $p <0.864265$) (Figure 11). Mildly stunted children were outperformed by the remainder of the children on the standing long jump and the ball throw tests (Sit-and-reach: $p < 0.280939$; Standing jump: $p < 0.0000001$; Sit-ups: $p < 0.282750$; Shuttle run: $p < 0.052940$; Ball throw: $p < 0.0000001$) (Figure 12). Figure 13 shows that children who were not moderately stunted significantly outperformed moderately stunted children on all physical fitness tests except the sit-and-reach test, for which the two groups showed an equal performance (Sit-and-reach: $p < 0.815466$; Standing jump: $p < 0.0000001$; Sit-ups: $p < 0.000019$; Shuttle run: $p < 0.000043$; Ball throw: $p < 0.0000001$). Although wasted children performed significantly better on the standing long jump test, they threw the cricket ball a shorter distance then their non-wasted counterparts (Standing jump: $p < 0.005316$; Ball throw: $p < 0.0000001$). There were no differences between the groups for the remaining physical fitness tests (Sit-and-reach: $p < 0.430985$; Sit-ups: $p < 0.088677$; Shuttle run: $p < 0.068880$) (Figure 14). There were no differences between the physical fitness scores of the underweight and non-underweight children for the sit-and-reach ($p < 0.455695$) and the shuttle run ($p < 0.257256$) tests. However, the underweight children were out performed on the standing jump ($p < 0.000040$), sit-up ($p < 0.000136$), and ball throw ($p < 0.0000001$) tests (Figure 15).

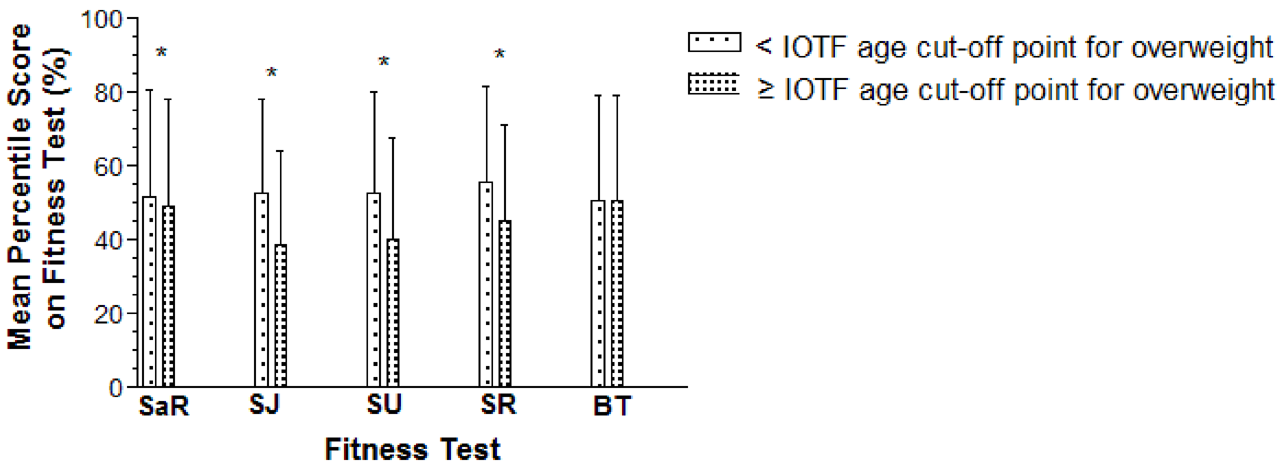

Figure 11: The differences between the physical fitness test scores of children classified as not overweight or obese compared to those classified as overweight or obese (IOTF definitions of over-nutrition (13)).

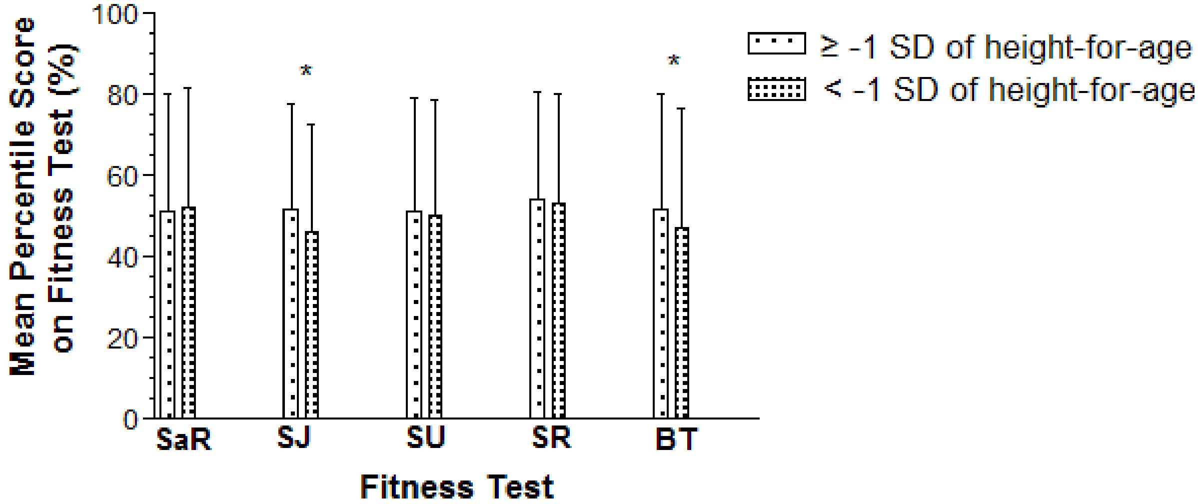

Figure 12: The differences between the physical fitness test scores of children classified as not mildly stunted compared to those classified as mildly stunted (WHO, 2007 definitions (6)).

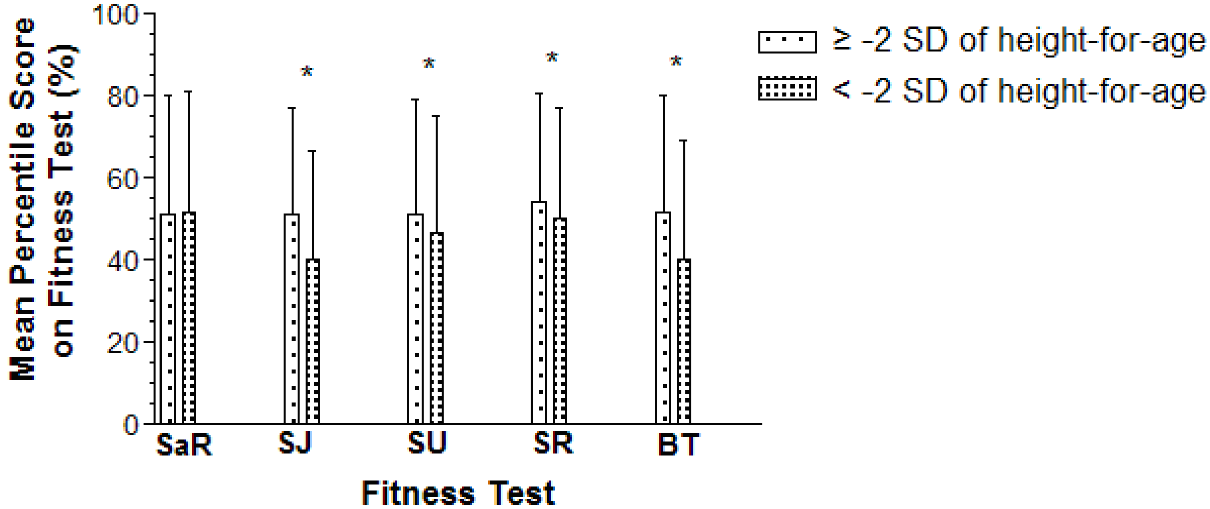

Figure 13: The differences between the physical fitness test scores of children classified as not moderately stunted compared to those classified as moderately stunted (WHO, 2007 definitions (6)).

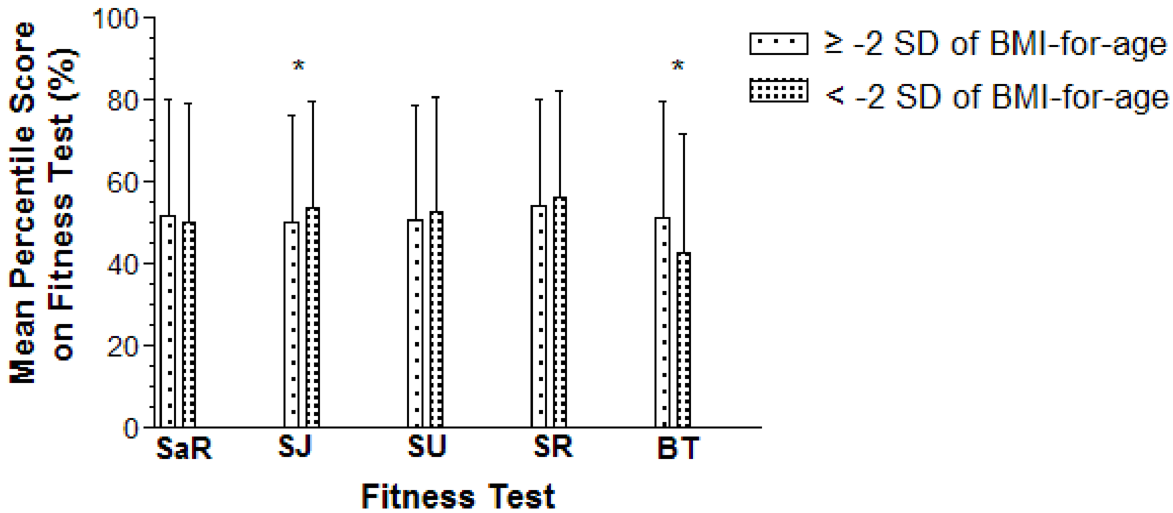

Figure 14: The differences between the physical fitness test scores of children classified as not wasted compared to those classified as wasted (WHO, 2007 definitions (6)).

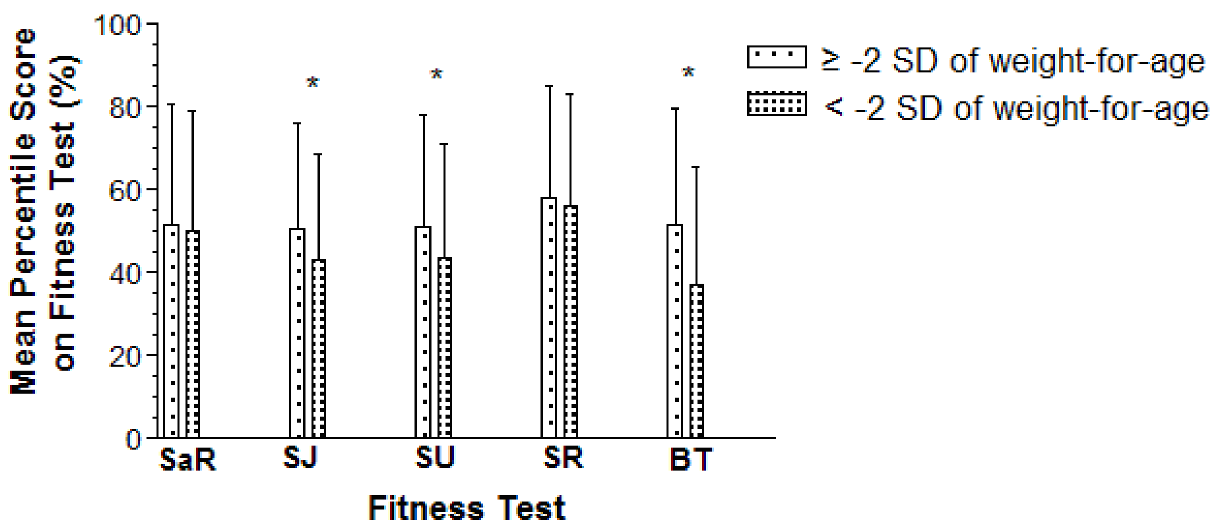

Figure 15: The differences between the physical fitness test scores of children classified as not underweight compared to those classified as underweight (WHO, 2007 definitions (6)).

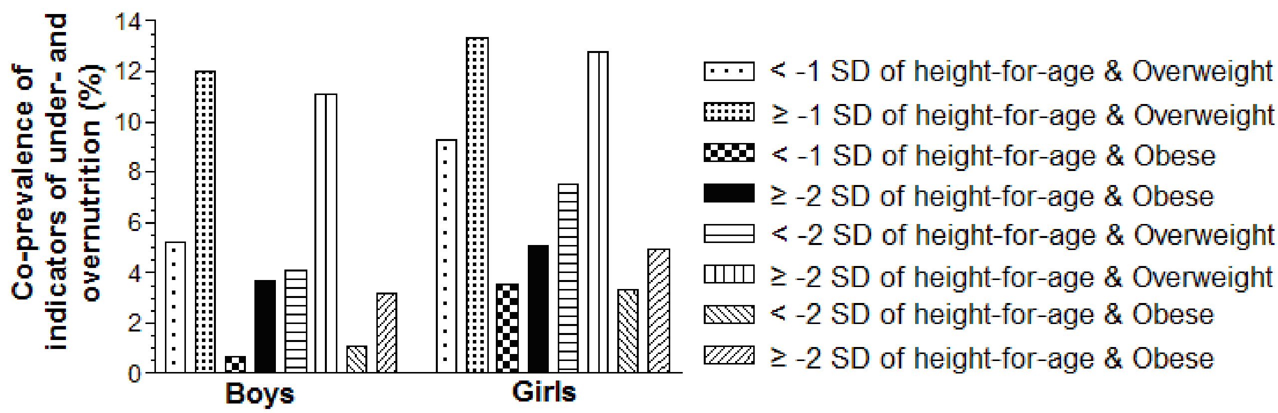

Figure 16: Prevalence of overweight or obesity (IOTF definitions of over-nutrition (13)) in mild and moderately stunted primary school children compared to those not classified as mild or moderately stunted (WHO, 2007 definitions (6)).

Figure 16 indicates that proportionally fewer children were overweight or obese among those classified as stunted or mildly stunted, when compared to non-stunted children. The absolute percentages were higher among the girls, although the relative differences were larger among the boys.

4.5 **Part 4: Socioeconomic Study**

The Socioeconomic Study aimed to assess whether the difference noted between the anthropometric and health-related fitness scores in the previous sections of this dissertation may, in part, be related to the disproportionate spread of the ethnic groups across the different socioeconomic strata in South Africa. A result of this disproportionate spread was that in some gender-by-age-by-ethnicity cells there were very few subjects. This was especially evident in the youngest age groups for the black children of highest socioeconomic status. However, as random sampling within the socioeconomic strata was necessary to allow the creation of representative national norms, little more could be done to avoid this artefact of the data. Figures are the main medium used in this section to illustrate the differences observed between the children from highest and lowest socioeconomic status. Tables of the actual values and sample sizes for all comparisons between the children from the lowest and highest socioeconomic status may be viewed in Appendix G: Socioeconomic Comparative Tables.

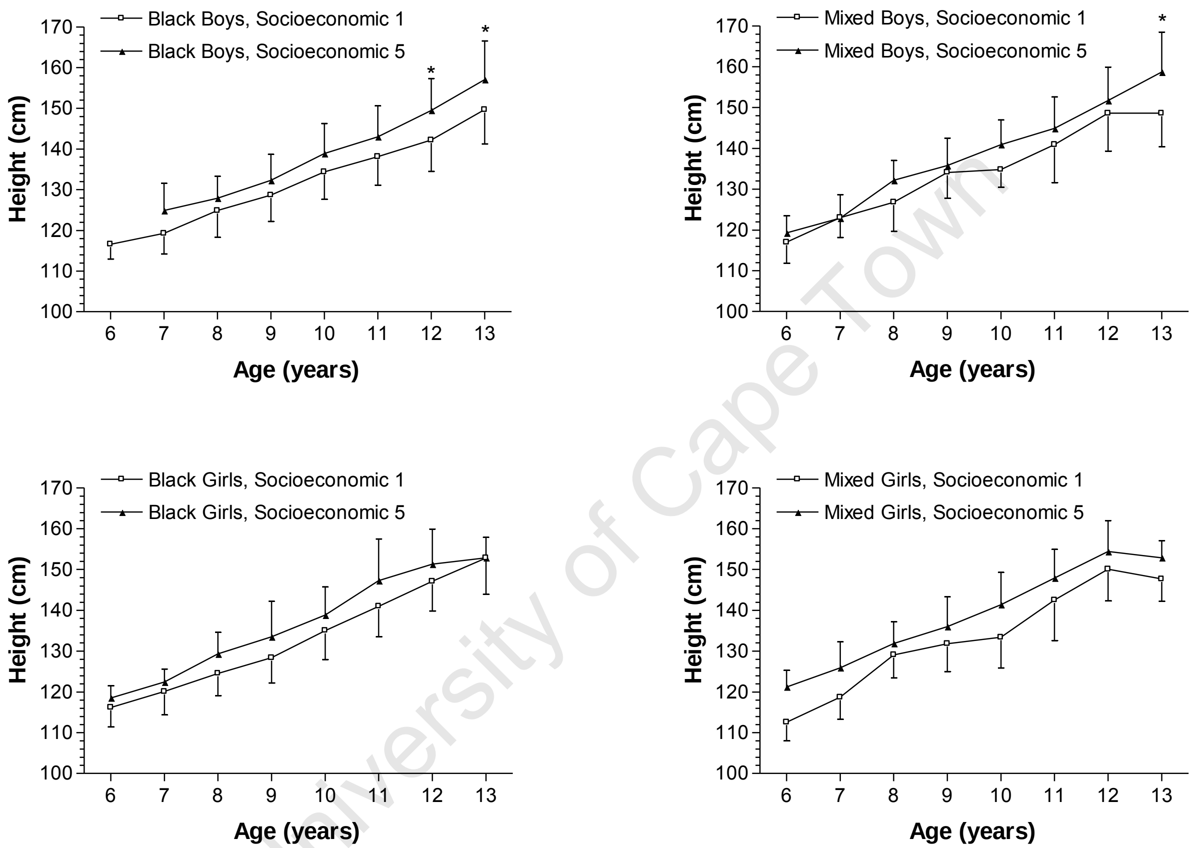

Figure 17: Comparisons between the height of children from the highest and lowest socioeconomic groups (Significant differences are indicated with *).

Among the highest socioeconomic group (socioeconomic group 5) there was a significant difference in height between the different ethnic groups among the boys ($F = 15.2$; $P < 0.0000001$) and the black and mixed ancestry girls ($F = 20.5$; $P < 0.0000001$). A univariate test of significance indicated a significant difference between the black and mixed ancestry boys in the lowest socioeconomic group (socioeconomic group 1) (F =

11.5; $P < 0.000729$), however the Unequal N HSD *post-hoc* test showed no significant difference between the ethnic groups. There was no significant difference between the heights of the girls of differing ethnicity in the lowest socioeconomic group (Non-significant: $F = 0.0$; $P < 0.901230$). The black boys ($F = 60.6$; $P < 0.0000001$) and girls ($F = 22.2$; $P < 0.0000003$), and mixed ancestry boys ($F = 25.1$; $P < 0.0000001$) and girls ($F = 40.6$; $P < 0.0000001$) from the highest socioeconomic group were taller than those from the lowest socioeconomic group (Figure 17).

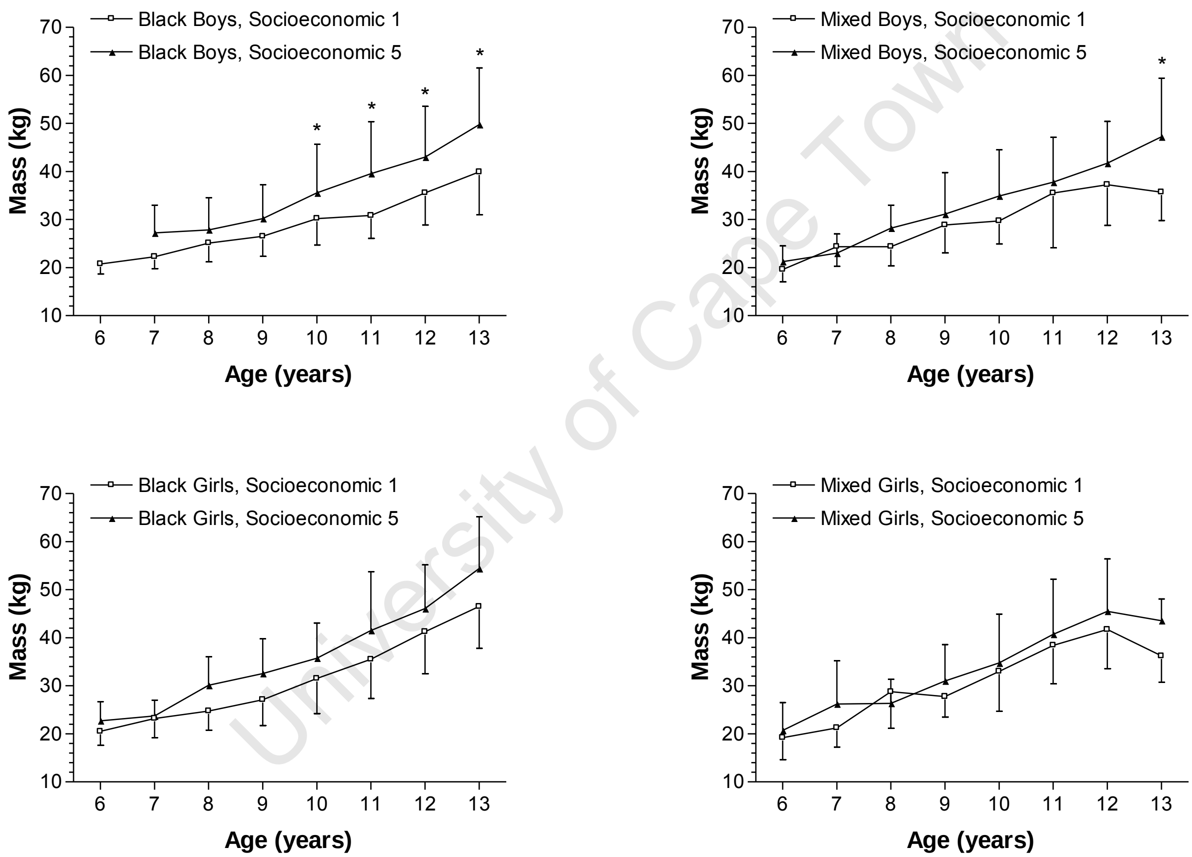

Figure 18: Comparisons between the mass of children from the highest and lowest socioeconomic groups (Significant differences are indicated with *).

There was a significant difference in the mass of the white boys when compared to the other ethnic groups in the highest socioeconomic category ($F = 8.8$; $P < 0.000162$). A univariate test of significance showed a significant difference between the weights of the different ethnic groups among the girls (F = 7.6; P < 0.000532), however *post-hoc* analysis showed no difference between the ethnic groups. There was no difference between the mass of the boys (Non-significant: F = 0.7; P < 0.399580), and girls (Non-significant: F = 0.4; P < 0.541021) in the lowest socioeconomic group. The masses of the black boys (F = 61.0; P < 0.0000001), and girls (F = 30.9; P < 0.0000001); and mixed ancestry boys (F = 14.7; P < 0.000138), and girls (F = 5.9; P < 0.015151) from the lowest socioeconomic group were significantly different from those of the highest socioeconomic group (Figure 18).

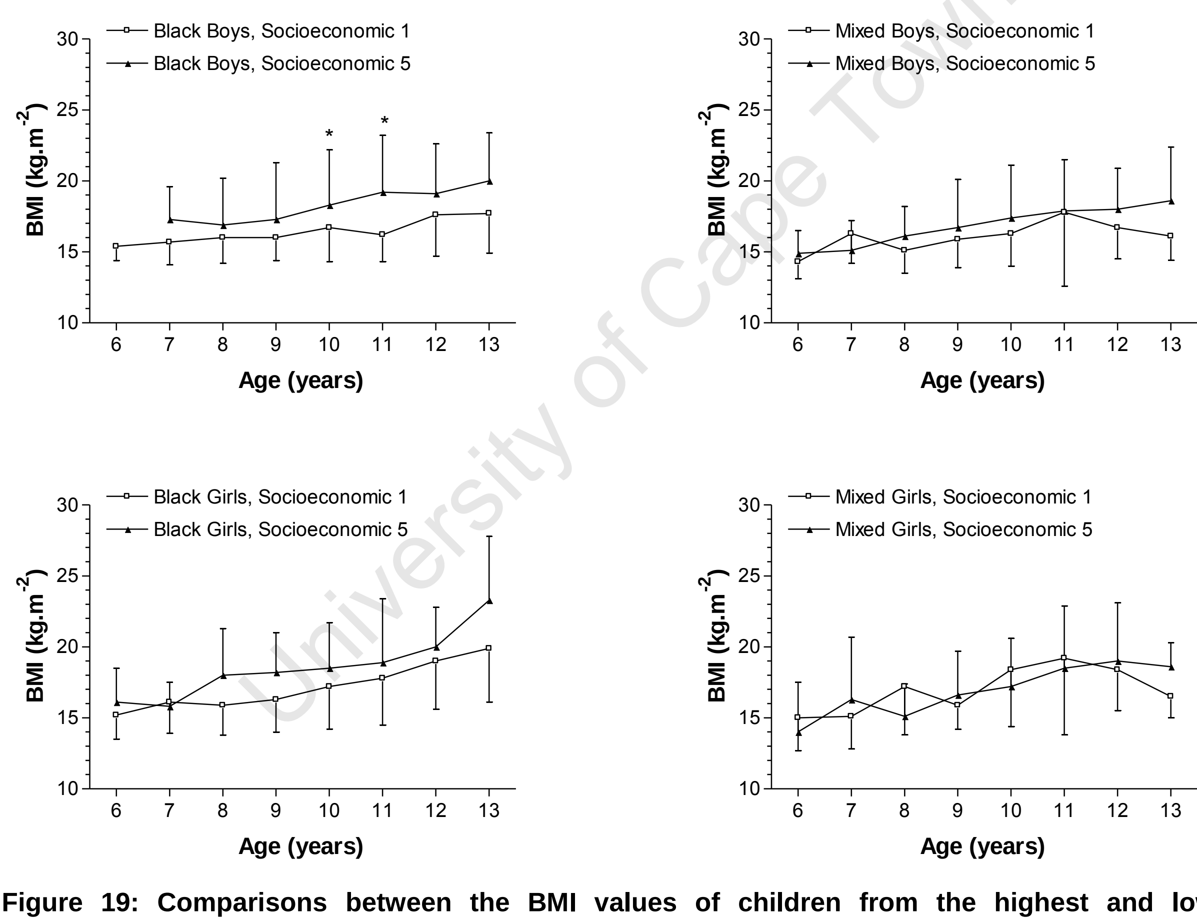

Figure 19: Comparisons between the BMI values of children from the highest and lowest socioeconomic groups (Significant differences are indicated with *).

In the highest socioeconomic group, the mixed ancestry boys had significantly lower BMI values than the other ethnic groups (F = 7.5; P < 0.000583). The black girls had significantly higher BMI values than the other ethnic groups among the girls of highest socioeconomic status (F = 9.2; P < 0.000111). The BMI values of boys (Non-significant: F = 1.9; P < 0.170986) and girls (Non-significant: F = 0.4; P < 0.541838) in the lowest socioeconomic group did not differ. The black boys (F = 28.0; P < 0.0000001) and girls (F = 16.4; P < 0.000056), and mixed ancestry boys (F = 4.4; P < 0.037008) from the highest socioeconomic group, had significantly different BMI values than those from the lowest socioeconomic group. No significant difference in BMI was noted between the high and low socioeconomic status girls of mixed ancestry (Non-significant: F = 0.0; P < 0.910675) (Figure 19).

Table XXXII: Percentage of mild stunting of black and mixed ancestry boys from high and low socioeconomic status, and white boys from high socioeconomic status (6 to 13 years). Values are expressed as percentages and sample size (n).

	Socioeconomic 1		Socioeconomic 5		
Age (yrs)	**Black**	**Mixed ancestry**	**Black**	**Mixed ancestry**	**White**
6	22.2 (27)	42.9 (7)	0.0 (2)	11.1 (9)	2.0 (51)
7	34.6 (52)	21.1 (19)	10.0 (10)	11.1 (18)	12.7 (134)
8	34.0 (97)	18.8 (16)	23.1 (39)	5.6 (36)	8.5 (200)
9	34.3 (105)	21.1 (19)	26.3 (38)	10.4 (67)	3.3 (275)
10	27.0 (115)	37.5 (16)	22.2 (63)	9.3 (97)	6.7 (300)
11	36.8 (117)	30.8 (13)	19.0 (42)	21.5 (93)	7.2 (418)
12	47.9 (117)	60.0 (20)	28.3 (46)	18.6 (70)	12.2 (468)
13	37.5 (128)	29.4 (17)	17.2 (29)	13.6 (22)	18.8 (213)
Adjusted Mean	**35.8 (758)**	**32.3 (127)**	**22.3 (269)**	**13.8 (412)**	**9.3 (2059)**

Table XXXIII: Percentage of mild stunting of black and mixed ancestry girls from high and low socioeconomic status, and white girls from high socioeconomic status (6 to 13 years). Values are expressed as percentages and sample size (n).

	Socioeconomic 1		Socioeconomic 5		
Age (yrs)	**Black**	**Mixed ancestry**	**Black**	**Mixed ancestry**	**White**
6	20.7 (29)	60.0 (5)	0.0 (5)	6.7 (15)	3.9 (51)
7	21.9 (64)	38.1 (21)	0.0 (8)	2.9 (35)	2.8 (143)
8	30.7 (114)	5.9 (17)	17.6 (17)	6.7 (30)	5.0 (199)
9	38.9 (113)	40.0 (10)	30.8 (13)	15.0 (60)	7.3 (219)
10	41.7 (120)	44.4 (9)	21.7 (23)	21.2 (66)	14.7 (204)
11	32.6 (144)	28.6 (14)	6.7 (15)	11.4 (79)	15.5 (174)
12	31.3 (134)	17.4 (23)	31,6 (19)	14.3 (70)	11.1 (180)
13	33.1 (133)	33.3 (6)	40.0 (10)	26.7 (15)	2.7 (75)
Adjusted Mean	**33.1 (851)**	**28.6 (105)**	**20.9 (110)**	**13.5 (370)**	**8.9 (1245)**

The prevalence of mild stunting was approximately twice as high among the children of lowest socioeconomic status when compared to those of the highest socioeconomic status. There was little difference between the adjusted mean values of black and mixed ancestry children in the lowest socioeconomic group. However, levels of mild stunting in the black children were twice as high as those of the white children, in the highest socioeconomic group (Table XXXV and Table XXXIII).

Table XXXIV: Percentage of moderate stunting of black and mixed ancestry boys from high and low socioeconomic status, and white boys from high socioeconomic status (6 to 13 years). Values are expressed as percentages and sample size (n).

	Socioeconomic 1		Socioeconomic 5		
Age (yrs)	**Black**	**Mixed ancestry**	**Black**	**Mixed ancestry**	**White**
6	0.0 (27)	0.0 (7)	0.0 (2)	0.0 (9)	0.0 (51)
7	15.4 (52)	0.0 (19)	10.0 (10)	11.1 (18)	1.5 (134)
8	15.5 (97)	12.5 (16)	2.6 (39)	0.0 (36)	1.0 (200)
9	16.2 (105)	0.0 (19)	5.3 (38)	1.5 (67)	1.5 (275)
10	15.7 (115)	6.3 (16)	6.3 (63)	1.0 (97)	1.7 (300)
11	21.4 (117)	15.4 (13)	11.9 (42)	3.2 (93)	1.0 (418)
12	23.1 (117)	5.0 (20)	6.5 (46)	4.3 (70)	1.1 (468)
13	25.8 (128)	41.2 (17)	17.2.(29)	9.1 (22)	2.8 (213)
Adjusted Mean	**18.9 (758)**	**10.2 (127)**	**7.8 (269)**	**2.9 (412)**	**1.4 (2059)**

Table XXXV: Percentage of moderate stunting of black and mixed ancestry girls from high and low socioeconomic status, and white girls from high socioeconomic status (6 to 13 years). Values are expressed as percentages and sample size (n).

	Socioeconomic 1		Socioeconomic 5		
Age (yrs)	**Black**	**Mixed ancestry**	**Black**	**Mixed ancestry**	**White**
6	3.4 (29)	0.0 (5)	0.0 (5)	0.0 (15)	0.0 (51)
7	10.9 (64)	14.3 (21)	0.0 (8)	2.9 (35)	0.0 (143)
8	8.8 (114)	5.9 (17)	0.0 (17)	0.0 (30)	1.0 (199)
9	15.9 (113)	0.0 (10)	7.7 (13)	0.0 (60)	0.5 (219)
10	15.0 (120)	22.2 (9)	8.7 (23)	1.5 (66)	1.0 (204)
11	20.1 (144)	7.1 (14)	13.3 (15)	3.8 (79)	2.3 (174)
12	20.1 (134)	13.0 (23)	5.3 (19)	4.3 (70)	1.1 (180)
13	11.3 (133)	33.3 (6)	0.0 (10)	0.0 (15)	0.0 (75)
Adjusted Mean	**14.7 (851)**	**11.4 (105)**	**5.5 (110)**	**2.2 (370)**	**0.9 (1245)**

The prevalence of moderate stunting in the highest socioeconomic group were less than half that of those in the lowest socioeconomic group. Among the highest socioeconomic group, white children had very low levels of moderate stunting when compared to the black children of both genders. Similar levels of moderate stunting were noted between the ethnic groups among the girls of lowest socioeconomic status. Differences between the boys of lowest socioeconomic status were larger, with the black children having the highest level of moderate stunting among the boys (Table XXXIV and Table XXXV).

Table XXXVI: Percentage of wasting of black and mixed ancestry boys from high and low socioeconomic status, and white boys from high socioeconomic status (6 to 13 years). Values are expressed as percentages and sample size (n).

	Socioeconomic 1		Socioeconomic 5		
Age (yrs)	**Black**	**Mixed ancestry**	**Black**	**Mixed ancestry**	**White**
6	7.4 (27)	14.3 (7)	0.0 (2)	11.1 (9)	2.0 (51)
7	3.8 (52)	5.6 (18)	0.0 (10)	11.1 (18)	2.2 (134)
8	3.1 (97)	18.8 (16)	2.6 (39)	8.3 (36)	3.5 (200)
9	3.8 (105)	5.3 (19)	2.6 (38)	9.0 (67)	5.1 (274)
10	6.1 (115)	12.5 (16)	1.6 (63)	8.2 (97)	5.7 (300)
11	10.3 (117)	15.4 (13)	0.0 (42)	10.8 (93)	4.3 (417)
12	10.3 (117)	15.0 (20)	4.3 (46)	7.1 (70)	4.7 (468)
13	10.9 (128)	29.4 (17)	3.4 (29)	9.1 (22)	4.2 (213)
Adjusted Mean	**7.4 (758)**	**14.3 (126)**	**2.2 (269)**	**9.0 (412)**	**4.4 (2057)**

Table XXXVII: Percentage of wasting of black and mixed ancestry girls from high and low socioeconomic status, and white girls from high socioeconomic status (6 to 13 years). Values are expressed as percentages and sample size (n).

	Socioeconomic 1		Socioeconomic 5		
Age (yrs)	**Black**	**Mixed ancestry**	**Black**	**Mixed ancestry**	**White**
6	0.0 (29)	0.0 (5)	0.0 (5)	46.7 (15)	5.9 (51)
7	3.1 (64)	19.0 (21)	12.5 (8)	20.0 (35)	4.9 (143)
8	6.1 (114)	0.0 (17)	0.0 (17)	13.3 (30)	8.5 (199)
9	0.9 (113)	10.0 (10)	7.7 (13)	6.7 (60)	4.6 (219)
10	3.3 (120)	0.0 (9)	4.3 (23)	6.1 (66)	3.4 (204)
11	6.9 (144)	0.0 (14)	0.0 (15)	5.1 (79)	5.2 (174)
12	2.2 (134)	0.0 (23)	5.3 (19)	10.0 (70)	3.3 (180)
13	5.3 (133)	0.0 (6)	0.0 (10)	0.0 (15)	4.0 (75)
Adjusted Mean	**4.0 (851)**	**4.8 (105)**	**3.6 (110)**	**10.0 (370)**	**5.0 (1245)**

Lower levels of wasting were noted among boys from highest socioeconomic status when compared to boys from lowest socioeconomic status of the same ethnicity. This trend was reversed among the mixed ancestry, but not black girls. In all gender and socioeconomic groupings, the mixed ancestry children showed higher levels of wasting than the other ethnic groups (Table XXXVI and Table XXXVII).

Table XXXVIII: Percentage of moderate stunting and wasting of black and mixed ancestry boys from high and low socioeconomic status, and white boys from high socioeconomic status (6 to 13 years). Values are expressed as percentages and sample size (n).

	Socioeconomic 1		Socioeconomic 5		
Age (yrs)	**Black**	**Mixed ancestry**	**Black**	**Mixed ancestry**	**White**
6	0.0 (27)	0.0 (7)	0.0 (2)	0.0 (9)	0.0 (51)
7	0.0 (52)	0.0 (18)	0.0 (10)	0.0 (18)	0.0 (134)
8	1.0 (97)	6.3 (16)	0.0 (39)	0.0 (36)	0.0 (200)
9	0.0 (105)	0.0 (19)	0.0 (38)	0.0 (67)	0.0 (274)
10	1.7 (115)	6.3 (16)	0.0 (63)	0.0 (97)	0.0 (300)
11	0.9 (117)	0.0 (13)	0.0 (42)	0.0 (93)	0.2 (417)
12	4.3 (117)	0.0 (20)	0.0 (46)	0.0 (70)	0.0 (468)
13	4.7 (128)	11.8 (17)	3.4 (29)	0.0 (22)	0.5 (213)
Adjusted Mean	**2.0 (758)**	**3.2 (126)**	**0.4 (269)**	**0.0 (412)**	**0.1 (2057)**

Table XXXIX: Percentage of moderate stunting and wasting of black and mixed ancestry girls from high and low socioeconomic status, and white girls from high socioeconomic status (6 to 13 years). Values are expressed as percentages and sample size (n).

	Socioeconomic 1		Socioeconomic 5		
Age (yrs)	Black	Mixed ancestry	Black	Mixed ancestry	White
6	0.0 (29)	0.0 (5)	0.0 (5)	0.0 (15)	0.0 (51)
7	0.0 (64)	0.0 (21)	0.0 (8)	0.0 (35)	0.0 (143)
8	1.8 (114)	0.0 (17)	0.0 (17)	0.0 (30)	0.0 (199)
9	0.0 (113)	0.0 (10)	0.0 (13)	0.0 (60)	0.0 (219)
10	0.0 (120)	0.0 (9)	0.0 (23)	0.0 (66)	0.0 (204)
11	2.1 (144)	0.0 (14)	0.0 (15)	1.3 (79)	0.0 (174)
12	1.5 (134)	0.0 (23)	0.0 (19)	0.0 (70)	0.6 (180)
13	0.0 (133)	0.0 (6)	0.0 (10)	0.0 (15)	0.0 (75)
Adjusted Mean	**0.8 (851)**	**0.0 (105)**	**0.0 (110)**	**0.3 (370)**	**0.1 (1245)**

The prevalence of the co-occurrence of moderate stunting and wasting was low in all of the groups. Among the boys, those of highest socioeconomic status showed lower prevalence of moderate stunting and wasting than those of lowest socioeconomic status. The opposite occurred between the highest and lowest socioeconomic status mixed ancestry, but not black girls (Table XXXVIII and Table XXXIX).

Table XL: Percentage of underweight black and mixed ancestry boys from high and low socioeconomic status, and white boys from high socioeconomic status (6 to 13 years). Values are expressed as percentages and sample size (n).

	Socioeconomic 1		Socioeconomic 5		
Age (yrs)	Black	Mixed ancestry	Black	Mixed ancestry	White
6	0.0 (28)	0.0 (7)	0.0 (2)	11.1 (9)	2.0 (51)
7	1.9 (52)	5.3 (19)	0.0 (10)	5.6 (18)	0.0 (134)
8	7.2 (97)	12.5 (16)	0.0 (39)	0.0 (36)	1.0 (200)
9	13.3 (105)	15.8 (19)	7.9 (38)	6.0 (67)	2.2 (274)
Adjusted Mean	**7.8 (282)**	**9.8 (61)**	**3.4 (89)**	**4.6 (130)**	**1.4 (659)**

Table XLI: Percentage of underweight black and mixed ancestry girls from high and low socioeconomic status, and white girls from high socioeconomic status (6 to 13 years). Values are expressed as percentages and sample size (n).

	Socioeconomic 1		Socioeconomic 5		
Age (yrs)	Black	Mixed ancestry	Black	Mixed ancestry	White
6	0.0 (29)	20.0 (5)	0.0 (5)	26.7 (15)	2.0 (51)
7	1.6 (64)	9.1 (22)	12.5 (8)	8.6 (35)	2.1 (143)
8	7.0 (114)	0.0 (17)	0.0 (17)	6.7 (30)	2.5 (199)
9	8.8 (113)	0.0 (10)	0.0 (13)	6.7 (60)	0.9 (219)
Adjusted Mean	**5.9 (320)**	**5.6 (54)**	**2.3 (43)**	**9.3 (140)**	**1.8 (612)**

The underweight prevalence was higher in boys of lowest socioeconomic status than those of highest socioeconomic status, for each ethnic group. Within the highest socioeconomic group, children of mixed ancestry showed higher levels of underweight than the other ethnic groups. Overall, mixed ancestry girls of the highest socioeconomic status showed the highest levels of underweight (Table XL and Table XLI).

Table XLII: Percentage of overweight black and mixed ancestry boys from high and low socioeconomic status, and white boys from high socioeconomic status (6 to 13 years). Values are expressed as percentages and sample size (n).

	Socioeconomic 1		Socioeconomic 5		
Age (yrs)	Black	Mixed ancestry	Black	Mixed ancestry	White
6	0.0 (27)	0.0 (7)	0.0 (2)	11.1 (9)	17.6 (51)
7	0.0 (52)	22.2 (18)	20.0 (10)	5.6 (18)	17.9 (134)
8	7.2 (97)	0.0 (16)	7.7 (39)	11.1 (36)	13.5 (200)
9	3.8 (105)	10.5 (19)	13.2 (38)	10.4 (67)	10.6 (274)
10	7.8 (115)	18.8 (16)	4.8 (63)	12.4 (97)	15.0 (300)
11	0.9 (117)	0.0 (13)	14.3 (42)	14.0 (93)	17.0 (417)
12	12.0 (117)	5.0 (20)	15.2 (46)	10.0 (70)	15.0 (468)
13	5.5 (128)	0.0 (17)	20.7 (29)	13.6 (22)	16.9 (213)
Adjusted Mean	**5.5 (758)**	**7.9 (126)**	**11.9 (269)**	**11.7 (412)**	**15.1 (2057)**

Table XLIII: Percentage of overweight black and mixed ancestry girls from high and low socioeconomic status, and white girls from high socioeconomic status (6 to 13 years). Values are expressed as percentages and sample size (n).

	Socioeconomic 1		Socioeconomic 5		
Age (yrs)	**Black**	**Mixed ancestry**	**Black**	**Mixed ancestry**	**White**
6	17.2 (29)	20.0 (5)	40.0 (5)	13.3 (15)	15.7 (51)
7	9.4 (64)	9.5 (21)	0.0 (8)	20.0 (35)	17.5 (143)
8	10.5 (114)	11.8 (17)	35.3 (17)	6.7 (30)	12.6 (199)
9	8.8 (113)	0.0 (10)	30.8 (13)	13.3 (60)	16.0 (219)
10	11.7 (120)	0.0 (9)	21.7 (23)	9.1 (66)	17.6 (204)
11	9.0 (144)	21.4 (14)	20 (15)	16.5 (79)	16.1 (174)
12	17.9 (134)	17.4 (23)	15.8 (19)	11.4 (70)	11.7 (180)
13	13.5 (133)	0.0 (6)	10.0 (10)	6.7 (15)	13.3 (75)
Adjusted Mean	**12.0 (851)**	**11.4 (105)**	**21.8 (110)**	**12.7 (370)**	**15.1 (1245)**

The prevalence of overweight was lower among the children from the lowest social class when compared to the highest social class. Differences between the overweight prevalence of mixed ancestry children were small between the two socioeconomic groups. However, the black children had twice the prevalence of overweight in the highest socioeconomic group when compared to the lowest socioeconomic group (Table XLII and Table XLIII).

Table XLIV: Percentage of obese black and mixed ancestry boys from high and low socioeconomic status, and white boys from high socioeconomic status (6 to 13 years). Values are expressed as percentages and sample size (n).

	Socioeconomic 1		Socioeconomic 5		
Age (yrs)	**Black**	**Mixed ancestry**	**Black**	**Mixed ancestry**	**White**
6	0.0 (27)	0.0 (7)	0.0 (2)	0.0 (9)	9.8 (51)
7	3.8 (52)	5.6 (18)	10.0 (10)	5.6 (18)	3.0 (134)
8	0.0 (97)	0.0 (16)	7.7 (39)	2.8 (36)	3.5 (200)
9	0.0 (105)	0.0 (19)	2.6 (38)	7.5 (67)	3.6 (274)
10	1.7 (115)	0.0 (16)	9.5 (63)	6.2 (97)	6.0 (300)
11	0.0 (117)	15.4 (13)	11.9 (42)	4.3 (93)	4.6 (417)
12	0.9 (117)	0.0 (20)	4.3 (46)	1.4 (70)	3.2 (468)
13	2.3 (128)	0.0 (17)	3.4 (29)	4.5 (22)	3.8 (213)
Adjusted Mean	**1.1 (758)**	**2.4 (126)**	**7.1 (269)**	**4.6 (412)**	**4.2 (2057)**

Table XLV: Percentage of obese black and mixed ancestry girls from high and low socioeconomic status, and white girls from high socioeconomic status (6 to 13 years). Values are expressed as percentages and sample size (n).

	Socioeconomic 1		Socioeconomic 5		
Age (yrs)	**Black**	**Mixed ancestry**	**Black**	**Mixed ancestry**	**White**
6	0.0 (29)	0.0 (5)	0.0 (5)	6.7 (15)	7.8 (51)
7	4.7 (64)	4.8 (21)	0.0 (8)	14.3 (35)	7.0 (143)
8	1.8 (114)	5.9 (17)	11.8 (17)	0.0 (30)	7.5 (199)
9	2.7 (113)	0.0 (10)	7.7 (13)	3.3 (60)	4.6 (219)
10	2.5 (120)	22.2 (9)	8.7 (23)	6.1 (66)	5.9 (204)
11	4.9 (144)	7.1 (14)	6.7 (15)	8.9 (79)	4.6 (174)
12	2.2 (134)	0.0 (23)	5.3 (19)	7.1 (70)	4.4 (180)
13	3.8 (133)	0.0 (6)	30.0 (10)	0.0 (15)	1.3 (75)
Adjusted Mean	**3.1 (851)**	**4.8 (105)**	**9.1 (110)**	**6.5 (370)**	**5.5 (1245)**

Both black and mixed ancestry children showed increased levels of obesity between the lowest and highest socioeconomic status children. This difference was more marked among the black children. Among the children from the highest socioeconomic group, the black children showed the highest prevalence of obesity and the white children the lowest (Table XLIV and Table XLVIII).

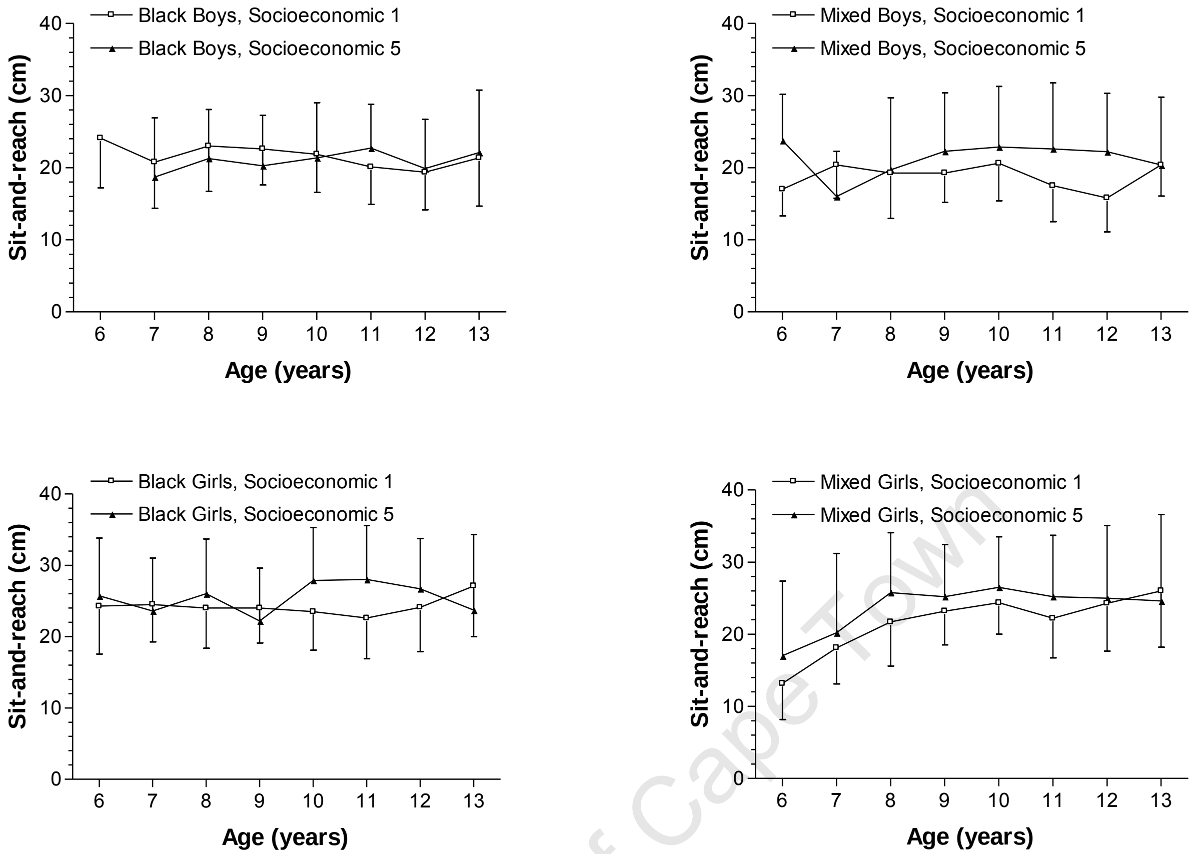

Figure 20: Comparisons between the sit-and-reach scores of children from the highest and lowest socioeconomic groups (Significant differences are indicated with *).

The sit-and-reach scores of the boys of highest socioeconomic status did not differ between the ethnic groups (Non-significant: $F = 0.4$; $P < 0.696037$). Among the highest socioeconomic group the mixed ancestry girls performed significantly poorer than the white girls ($F = 9.0$; $P < 0.000136$). The mixed ancestry boys ($F = 24.8$; $P < 0.0000001$) and girls ($F = 14.1$; $P < 0.000183$) had significantly lower sit-and-reach scores than the black children in the lowest socioeconomic group.

There was no difference between the sit-and-reach scores of black boys (Non-significant: $F = 2.5$; $P < 0.110895$) and girls (Non-significant: $F = 3.6$; $P < 0.058654$), and mixed ancestry girls (Non-significant: $F = 3.7$; $P < 0.055840$) from high and low socioeconomic status. However, the sit-and-reach scores of the mixed ancestry boys were significantly different between the high and low socioeconomic groups (F = 7.2; P < 0.007353) (Figure 20).

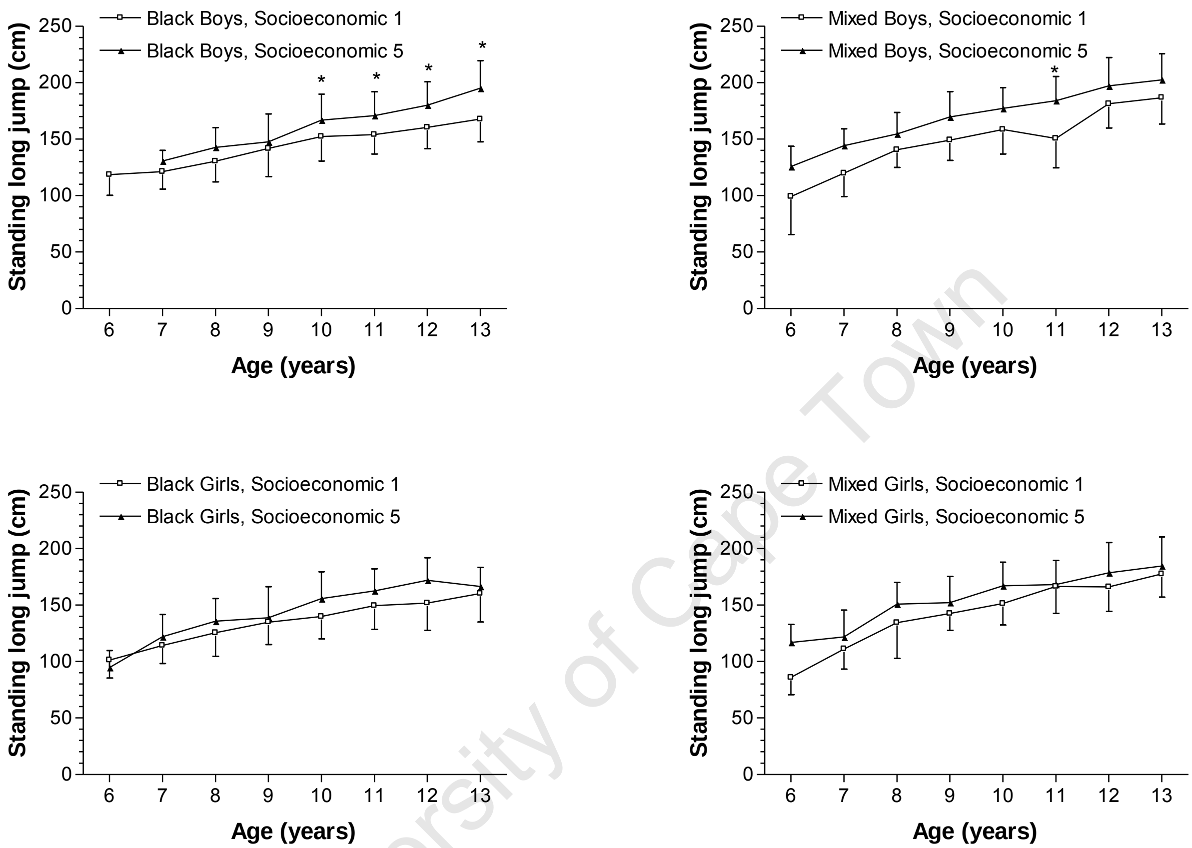

Figure 21: Comparisons between the standing long jump scores of children from the highest and lowest socioeconomic groups (Significant differences are indicated with *).

The black children jumped a significantly shorter distance than the other boys (F = 8.0; P < 0.000346) and girls (F = 20.9; P < 0.0000001) in the highest socioeconomic group. Although the Univariate test of significance showed a difference between black and mixed ancestry boys (F = 5.6; P < 0.017943) and girls (F = 8.4; P < 0.003951) in the lowest socioeconomic group, the Unequal N HSD *post-hoc* test showed no difference.

Standing long jump scores of the black (F = 42.6; P < 0.0000001) and mixed ancestry (F = 72.9; P < 0.0000001) boys of high socioeconomic status were significantly greater than those of low socioeconomic status. The black (F = 13.3; P < 0.000275) and mixed ancestry (F = 20.5; P < 0.000008) girls also showed significant differences between the standing long jump scores of the children of lowest and highest socioeconomic status (Figure 21).

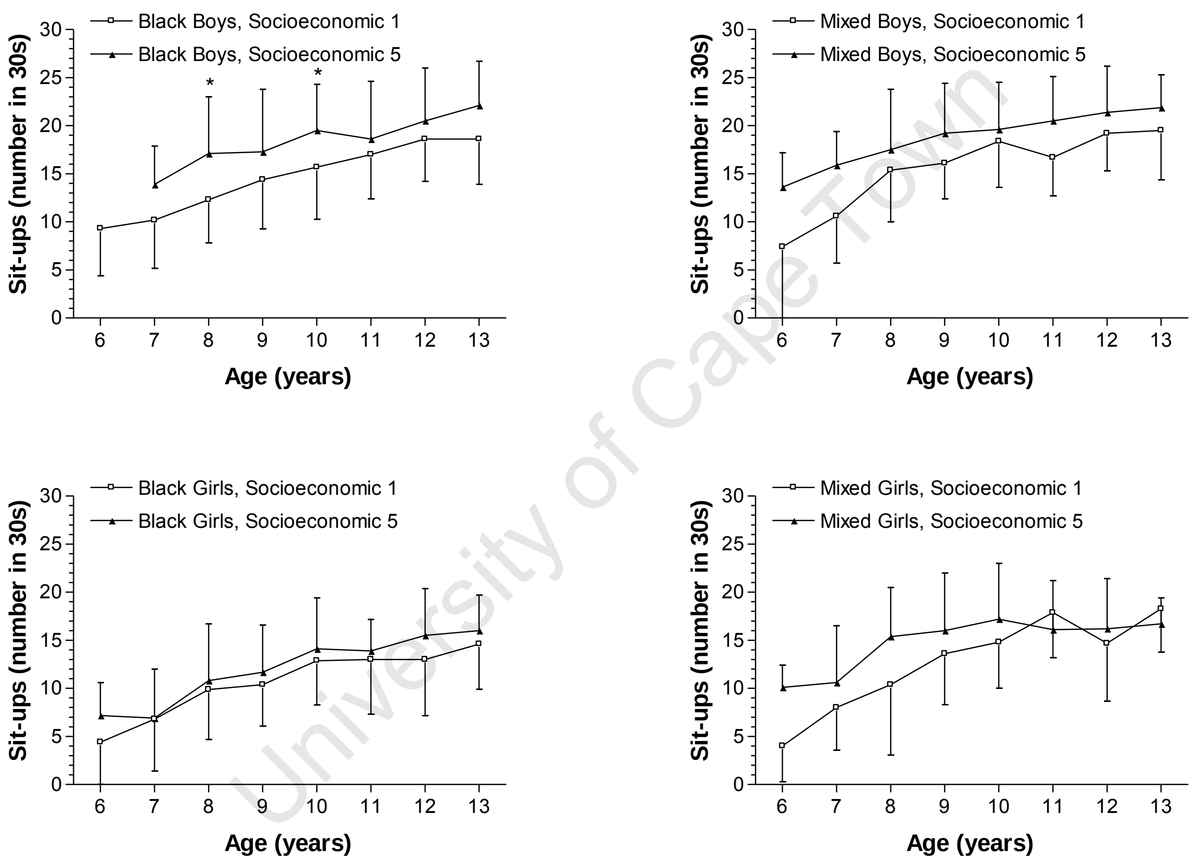

Figure 22: Comparisons between the sit-up scores of children from the highest and lowest socioeconomic groups (Significant differences are indicated with *).

The number of sit-ups completed in 30 seconds by the boys from the highest socioeconomic group was not different between the different ethnicities (Non-significant: F = 2.2; P < 0.115670). However, among the girls of highest socioeconomic status, the black children performed significantly poorer than the other ethnic groups on the sit-up test (F = 17.4, P < 0.0000001). There was no significant difference between the sit-up scores of the boys from the lowest socioeconomic group (Non-significant: F = 3.1; 0.077649). The Univariate test of significance showed a significant difference between the sit-up scores of girls in the lowest socioeconomic status group (F = 11.7; 0.000683). However, no significant differences were noted in the Unequal N HSD *post-hoc* test, between these two groups.

Black (F = 29.6; P < 0.0000001) and mixed ancestry (F = 35.0; P < 0.000001) boys from the highest socioeconomic category completed significantly more sit-ups in 30 seconds than those from the lowest socioeconomic category. The sit-up scores of the lowest and highest socioeconomic status black (F = 5.8; P < 0.015971) and mixed ancestry (F = 9.1; P < 0.002699) girls were also significantly different (Figure 22).

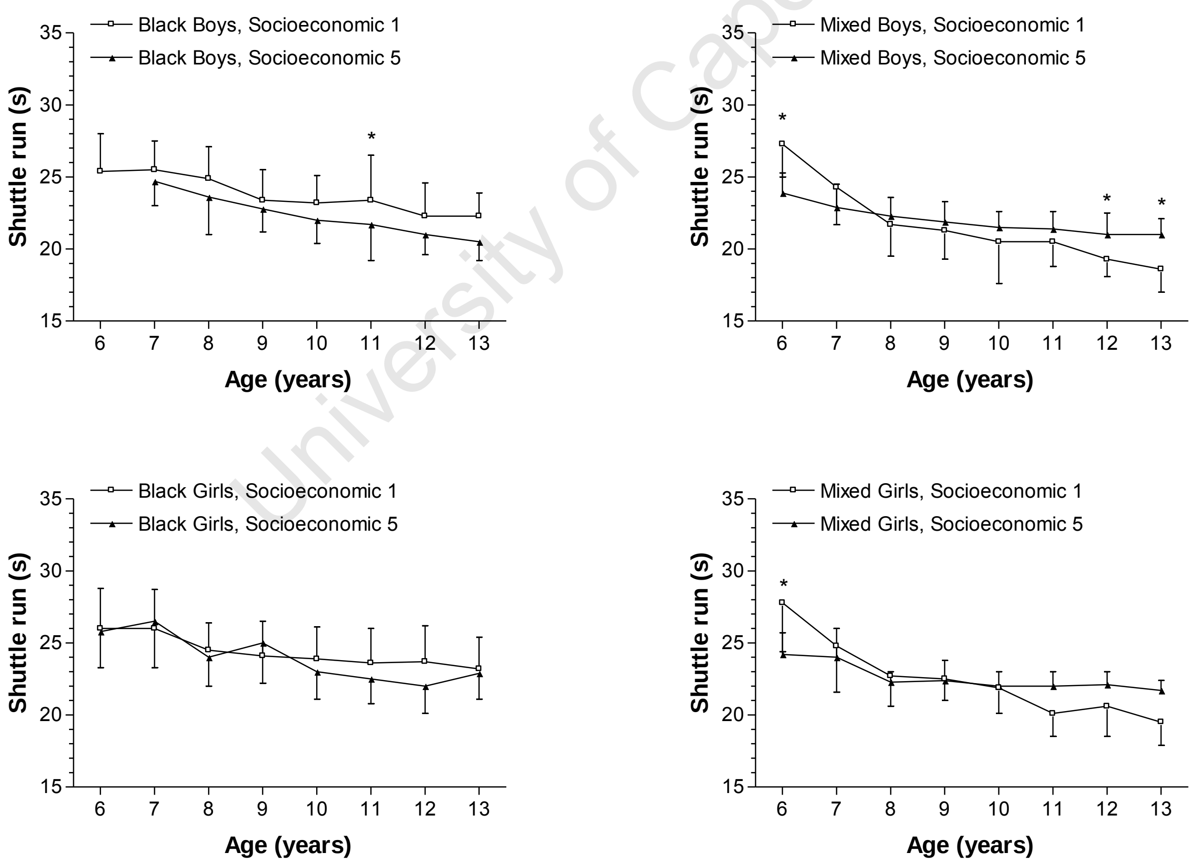

Figure 23: Comparisons between the shuttle run scores of children from the highest and lowest socioeconomic groups (Significant differences are indicated with *).

The black boys (F = 12.6; P < 0.000003) and girls (F = 46.0; P < 0.0000001) took significantly longer to complete the shuttle run than the white and mixed ancestry children in the highest socioeconomic group. The black boys (F = 84.9; P < 0.0000001) and girls (F = 47.5; P < 0.0000001) also took the longest time to complete the shuttle run in the lowest socioeconomic group.

Low socioeconomic status black boys took a significantly longer time to complete the shuttle run than high socioeconomic status black boys (F = 19.8; P < 0.000009). There was no significant difference between the shuttle run times of the highest and lowest socioeconomic status black (Non-significant: F = 2.7; P < 0.101766) and mixed ancestry girls (Non-significant: F = 0.3; P < 0.603746), and mixed ancestry boys (Non-significant: F = 2.7; P < 0.101173) (Figure 23).

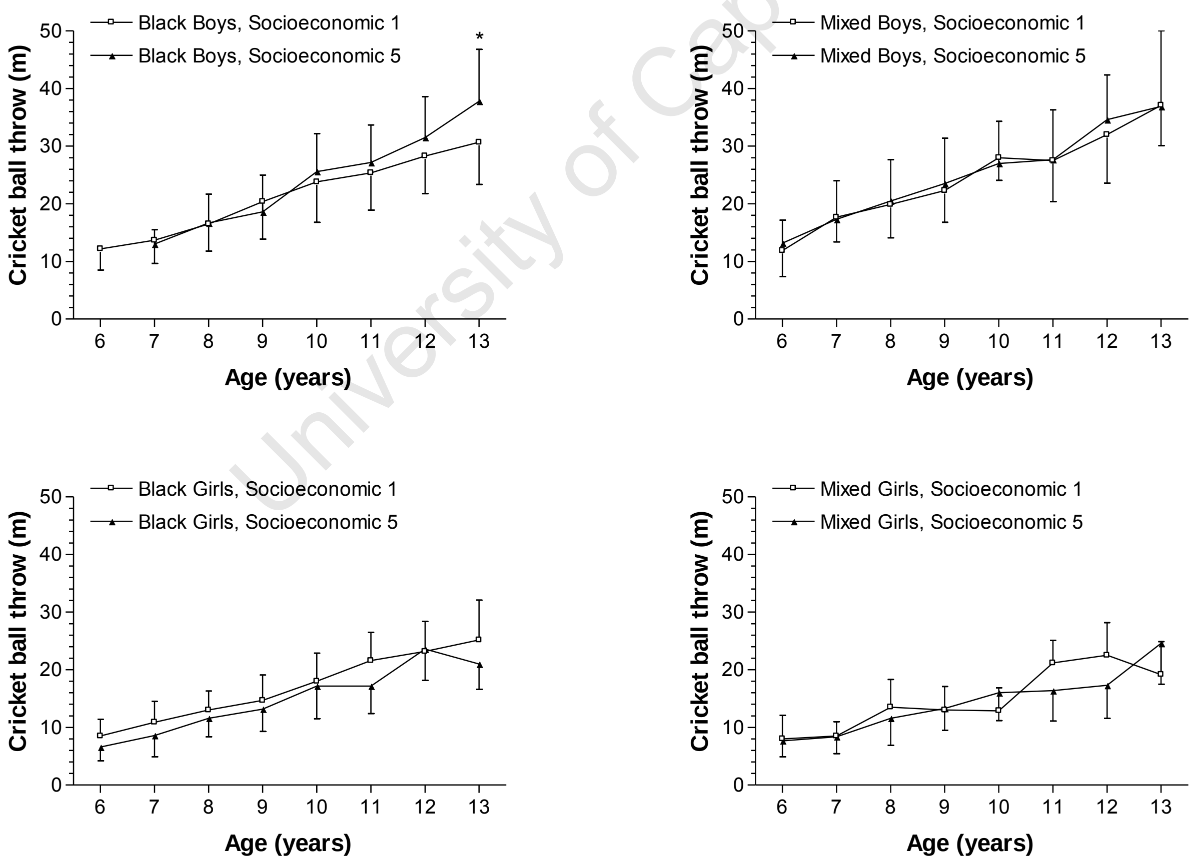

Figure 24: Comparisons between the cricket ball throw scores of children from the highest and lowest socioeconomic groups (Significant differences are indicated with *).

Among the boys from the highest socioeconomic status, the distance thrown in the cricket ball throw test was significantly different when comparing boys from different ethnic groups ($F = 4.2$; $P < 0.015633$). Within the group of girls representing the highest socioeconomic group, the distance thrown by the white girls was significantly less than the other ethnicities ($F = 8.1$; $P < 0.000313$). The mixed ancestry boys ($F = 24.8$; $P < 0.000001$) and girls ($F = 12.3$; $P < 0.000473$) threw a significantly shorter distance then the black children in the lowest socioeconomic group. The ball throw scores for black boys ($F = 11.3$; $P < 0.000804$) and girls ($F = 12.7$; $P < 0.000375$) of high socioeconomic status were significantly different from those of low socioeconomic status. There was no significant difference between the ball throw scores of the lowest and highest socioeconomic status mixed ancestry boys (Non-significant: $F = 0.4$; $P < 0.522893$) and girls (Non-significant: $F = 0.5$; $P < 0.478804$) (Figure 24).

4.6 Summary of findings

White children were generally taller and heavier than black children. However, there was little difference between the BMI values of the children from different ethnic groups. A nutritional analysis indicated that black children showed the highest levels of both mild and moderate stunting. Mixed ancestry children of both genders had the highest prevalence of wasting. The co-occurrence of stunting and wasting was low among all ethnic groups. White children had the lowest prevalence of underweight. Conversely, overweight and obesity prevalence was highest among this ethnic group.

White children generally had the highest scores on the tests of physical fitness, with black children scoring the lowest. The performance of mixed ancestry children tended to fall between the other two ethnic groups. However, flexibility scores were similar between all groups, and older black girls scored the highest on the cricket ball throw test among the girls.

The performance scores of the overweight children were lower for all the tests except the cricket ball throw, for which there was no difference between the groups. Stunted and underweight children tended to perform significantly poorer than the rest of the sample on the majority of the tests of physical fitness. Wasted children showed a slightly different profile to these two groups, performing significantly better than non-wasted children on the standing long jump test. There was no significant difference between the levels of overweight and obesity of children classified as stunted and those of normal height-for-age.

The socioeconomic study indicated that children from low socioeconomic status tended to be shorter and weigh less than those of high socioeconomic status from the same ethnic group. The prevalence of stunting was much lower in the higher socioeconomic groups. Wasting, wasting and stunting, and underweight prevalence followed this same trend among the males. Conversely, high socioeconomic status mixed ancestry girls had a higher prevalence than their low socioeconomic status counterparts for all three of these conditions. Obesity and overweight levels were higher among the children from highest socioeconomic status, with black children having the highest levels of obesity. Although there was little consistent difference between the sit-and-reach scores of the high versus low socioeconomic status children, high socioeconomic status children generally outperformed the low socioeconomic status children on the standing long jump and sit-up tests. The shuttle run test scores differed between the high and low socioeconomic status children; however which group gave the better performance was dependant on age. Differences between the cricket ball throw scores of the different socioeconomic groups were small with no consistent trends across ethnicity and gender.

The findings of this thesis provide a systematic summary of the present nutritional status and baseline levels of physical fitness for the South African primary school population. The influence on these factors according to ethnic and socioeconomic classification is also considered to provide insight into the legacy left by apartheid. The results of these analyses are discussed in greater detail in the following chapter.

CHAPTER 5

DISCUSSION AND CONCLUSIONS

5.1 Introduction

This chapter discusses the results of each of the four studies before reaching conclusions from these findings. As in previous chapters, the discussion and conclusions are each separated into four different parts, according to the different studies described in this thesis. This chapter concludes with an overview of the limitations of the techniques and data presented in this thesis and provides direction for future studies arising from the findings of this thesis.

5.2 Part 1: Nutritional Status Study

Concern for the health of South African children has risen from an awareness of international trends in paediatric overweight and obesity coupled with the results of the National Food Consumption Survey (471) and some factors identified by the Birth to Twenty study, the longest running and largest longitudinal study of paediatric health and development in Africa (16). Jinabhai et al., (10) also pointed out the need to monitor the nutritional status of young South Africans to track a possible nutritional transition. Therefore, the need to identify the nutritional status of South African children of all ethnicities and social backgrounds is important so that effective intervention programmes can be implemented at an early stage.

The first finding from this study was that although there were a number of significant differences between the heights and weights of the children from different ethnic groupings, BMI values only displayed one difference; that between 13 year old mixed ancestry and white boys. The Birth to Twenty Study (16) showed that when children were grouped according to activity levels, the most active children weighed approximately 2 kg more and were about 3 cm taller than those children who were least active. Consequently, whether this is as a result of ethnic, nutritional, or physical activity level differences, or a combination of these factors is unknown. Caradas et al. (69) conducted a study on a relatively small sample of South African school girls aged 15 to 18 years. This study showed that black girls were significantly shorter and weighed more and thus had a higher BMI than white and mixed ancestry girls. However, this was not evident within the current sample of 6 to 13 year olds. Therefore, this could be a trend which only becomes evident following puberty within the South African paediatric population. This hypothesis may be supported by noting that with increased age the combined percentage of overweight and obese black girls within the sample increased from 11.9% at 6 years to 21.8% at 13 years (Table XX). An opposite trend was evident among the white girls (from 25.4% at 6 years to 14.5% at 13 years) (Table XX). It is postulated that these trends may in part result from increased awareness of cultural differences with age. Mciza et al. (70) considered body image perception, body size dissatisfaction and weight-related beliefs of 9 to 12 year old South African girls. They found that when ask to select a 'normal weight' girl from a range of silhouettes, black girls generally chose a larger silhouette to represent 'normal weight' then white girls, indicating a preference for a larger body size among black girls (70). Further to this, Mvo et al. (24) noted that it is often desirous for girls to be overweight within the African culture as it indicates wealth and happiness. Whereas, white girls may be more heavily influenced by the Western beauty ideal, which shuns fatness (68). Additionally, Clark et al. (68) stressed that obesity and overweight within the African culture, may serve to show that a person is without Human Immunodeficiency Virus (HIV) or Acquired Immunodeficiency Syndrome (AIDS). This influence is important considering the current AIDS epidemic in sub-Saharan Africa.

Differences in the anthropometric markers of under-nutrition were noted between the ethnic groups. According to the national demographically adjusted averages, boys showed slightly higher levels of both mild and moderate stunting when compared to girls. The prevalence of mild stunting among white boys was one-third and one-half of that reported in black and mixed ancestry boys respectively, according to the WHO 2007 reference (6). Among the girls the differences between the ethnic groups were similar to the differences which occurred in the boys. Differences were even larger according to the 1978 CDC/WHO (7) reference. The prevalence of moderate stunting of black children was twice that of mixed ancestry children. Prevalence of moderate stunting among white children was much lower, at approximately one-twelfth that of black children. When differences are found between ethnic groups, the possibility that these results have been confounded by social class should be considered (438). The majority of black children are concentrated within the lower socioeconomic groups in South Africa and therefore it is likely that parts of these differences are related to differences in social class. This will be examined later in this dissertation.

The population prevalence of mild and moderate stunting was lowest in the younger age groups, and increased with age. This trend was especially evident among the black children who constitute the largest section of the South African population. Stunting often results when infants and young children are exposed to under-nutrition and in many cases stunted children do not recover a normal height-for-age (27). Therefore, this finding is consistent with poorer socioeconomic conditions prevailing during the infancy of the elder children when compared to the younger children in this sample.

The prevalence of wasting was approximately twice as high in mixed ancestry children when compared to white children of both genders. Black children had a wasting prevalence of approximately two-thirds that of the mixed ancestry children. This finding prompts the questions of why black children showed the highest rates of stunting whereas mixed ancestry children had the highest prevalence of wasting in the sample. Traditionally, wasting is a measure of acute under-nutrition, whereas stunting has been associated with past or long term under-nutrition (25). In addition to this, Victora (472) showed that strong correlations did not consistently occur between the prevalence rates of wasting and stunting in different regions and countries. Together these factors suggest that the aetiology of stunting and wasting may differ. Therefore, these different ethnic groups may be exposed to, or react differently to triggers in their physical or social environment which are associated with wasting and stunting.

Whereas the prevalence of wasting in boys was much increased at 13 years when compared to six years of age, wasting prevalence remained fairly constant across the age range in girls. As those of black ethnicity constitute the largest proportion of the South African population, trends in their data have the greatest effect on trends in the demographically adjusted mean values for South Africa as a whole. Earlier analysis showed that black boys and girls were the shortest in the sample. Black boys also weighed significantly less than other groups, whereas little difference was seen in the mass of the girls in the sample. Chronic under-nutrition, as evidenced by the levels of stunting in this sample, has been shown to delay the onset of sexual maturity and the adolescent growth spurt (49); (50); (48). Although sexual maturity was not assessed in this study, it may explain the increased levels of wasting among black 13 year old boys. In girls this effect may have been tempered by relatively higher body weights as a result of the African culture favouring an overweight body shape among girls (70).

The co-prevalence of wasting and stunting was low among boys and girls. White children consistently showed the lowest co-prevalence rates, with a difference of about one percent or less between the different ethnic groups. Underweight prevalence was similar between the black and mixed ancestry children. On average, white boys had a prevalence one-sixth that of the other ethnic groups. White girls showed a smaller difference; with prevalence approximately three-times lower than the other ethnicities. Again, it is proposed that this difference is related to differences in the distribution of the ethnic groups across the socioeconomic strata in South Africa.

Classifications according to the WHO 2007 normative curves (6) were higher than those made according to the 1978 CDC/WHO (7) norms for all measures of under-nutrition except wasting. Even though these two references are to a large degree based on the same population, the WHO 2007 reference (6) excluded all children with an unhealthy level of over-nutrition. This resulted in an upward shift of the curves and cut-off points with the consequence that more children fell into the undernourished category (35). The different trend in wasting noted between the two different references results from the use of different underlying measures. The WHO (2007) (6) measure of wasting considers a deficit in BMI-for-age, whereas the 1978 CDC/WHO (7) data uses a deficit in weight-for-height to assess this same measure. Overall, boys showed slightly higher levels for all measures of under-nutrition, whereas girls had higher levels of over-nutrition.

When odds ratios were calculated for the prevalence of each nutritional condition with respect to the demographically adjusted population prevalence rates, few significant differences were noted. Black children constitute a high proportion of the South African population so it is unlikely that odds ratios would show them to be at increased risk for developing any of the reported nutritional conditions in comparison to the demographically adjusted population means. However, white children were at a significantly lowered risk of being mildly or moderately stunted when compared to the population. As stunting is a condition associated with lack, and white children are concentrated within the highest socioeconomic strata, this finding is as expected. It is also important to consider that children from the lowest socioeconomic strata are subject to insufficient household food security, health services and often poor maternal care resulting from an inadequate education (29). These factors frequently result in a poor dietary intake and disease, which ultimately lead to malnutrition and increased levels of mortality among young children (29). Therefore, school-age children from the lowest socioeconomic groups in this study may be considered survivors of this selective process.

Since the early 1990's, the South African government has aimed to improve the socioeconomic status of many previously disadvantaged groups. The reporting of secular trends in the nutritional status of South African children may aid in determining the effectiveness of these government policy changes. This analysis of secular trends revealed both positive and negative results. The national prevalence of mild stunting decreased by 10% in boys and by 20% in girls in comparison to the values of the mid 1990s for 8 to 11 year olds (10). This implies that levels of mild stunting decreased by approximately one third in boys and was halved in girls, in the decade preceding this data collection period. Moderate stunting in this same age range showed even larger relative decreases with a five-fold decrease in both boys and girls. Absolute decreases of 10% in boys and 14% in girls were noted in the population prevalence rates of moderate stunting (10).

The levels of wasting reported among 7 to 9 year olds in the mid 1990s were low, at less than 4% (12). The present study shows only a slight decrease in comparison to these values. According to the National Food Consumption Survey

(12), 8% of 7 to 9 year olds were classified as underweight in the mid 1990s. The present study showed a 3.5-fold decrease among boys and a 5.3-fold decrease among girls in underweight prevalence in this age range.

A negative result of this transition has been the alarming increase noted in overweight and obesity prevalence. When compared to data gathered on 8 to 11 year old children in 1994 (10), there has been a seven-fold increase in the overweight prevalence of boys and an eight-fold increase in the same measure among girls. Twelve times more boys and 22 times more girls are classified as obese, than the prevalence rates reported a decade prior to the data collected for the present study. This rapid rise in the levels of over-nutrition among young South Africans is highly concerning. However, as increased levels of physical activity among young South Africans have been associated with favourable body composition, physical activity needs to become an important public health message in South Africa (473). Therefore, it is hoped that the Vitality Schools fitness programme due to be launched in South Africa in 2009 as an output from this research will contribute in a substantial way towards ameliorating this health crisis. Further details on this programme are available in Appendix D: Software.

There are always methodological constraints when normative data from different countries are compared. Until recently, the debate over appropriate methods of classification for overweight and obesity within the paediatric population has resulted in an inability to make meaningful international comparisons (55). Recently, internationally derived cut-off points (13) have created more meaningful classifications that can be used for comparative purposes. However, there is paucity in the information from national surveys which has since been classified into this format. When considering the age group sampled in the South African Health of the Nation survey, the most recent comparative data using the method of Cole et al. (13) is that of datasets from 1980 to 1994, that is, datasets which are over 10 years old.

The next finding was that when compared to datasets from within and before the 1980s, the South African sample displayed values much higher than the other countries, except the United States (Table XXII). Datasets from other countries in the mid 1990s were closer to the present South African sample but were still consistently lower than South Africa, with the exception of the United States. On average South African children showed very similar overweight and obesity values to children from the United States between 1976 and 1980, with South African boys slightly below reported United States values and South African girls slightly above. The described prevalence of overweight and obesity in the United States by 1994 was higher than in all South African groups considered. However, when split into ethnic groups, the white South African children were within less then 3% of all of the United States values for the 1988-1994 sample (89). The black girls displayed relatively high values, 6.7% less for overweight and 3.5% less for obesity, than the United States girls, whereas black boys were less than half as likely to be overweight than those in the United States group. This follows a similar trend to that observed within the black South African adult population (3). An editorial released in 2002 (16) indicated that less than one third of black children were offered physical education at school. Subsequent to the publication of these statistics, formal physical education classes have become part of the life skills section of the national South African curriculum, thereby deemphasizing the importance of physical activity within the educational context. This information in association with the above results shows the need to address the risks associated with modern society and increased sedentary living within the South African context as a matter of urgency, to combat any further increase in the levels of overweight and obesity among South African children.

5.3 Part 2: Physical Fitness Study

There is growing recognition of the important role of physical activity and fitness in reducing the risk of non-communicable diseases, and enhancing health and well-being (474). However, there is also evidence world-wide that vulnerable groups for low levels of activity and declining levels of health-enhancing fitness include children and youth (475). Preliminary data from South Africa confirms this global trend, where levels of physical activity in children have been inversely associated with overweight and obesity, and television viewing time is also higher in children who are more overweight (476). The main aim of this study was to create baseline health-related physical fitness measurements for a wide spectrum of South African primary school children, according to ethnic grouping. The ultimate goals were to establish a reference point for longitudinal studies within the South African population and to compare present South African children to their international counterparts.

Differences in height and mass were observed between the different ethnic groups, with the white children being the tallest and heaviest and the black children the shortest and lightest across both genders. However, few differences were noted between the BMI's of the different groups. These anthropometric differences are likely to have an important role in the differences observed on physical fitness test scores between children of different ethnic groups. This is particularly evident in the standing long jump test. The scores of the black children were significantly lower than those of the mixed ancestry and white children in both genders (Table XXIV). The mixed ancestry and white boys jumped a distance on average 20 cm or more than that of the black boys. This difference was not as large among the group of girls (approximately 17 cm). Difference in maturational status of children for any given chronological age, accompanied with assumptions concerning body size, may be expected to affect performance scores in tests of motor skills (333). This study did not specifically assess maturational status, however height and weight differences resulting from differing maturity levels between ethnic groups are likely to account in part for the differences noted in the standing long jump scores between these groups. Black boys were approximately 10 cm shorter than white boys, and black girls approximately 5 cm shorter than white girls (Table V). Additionally, white boys weighed over 6 kg more than black boys, and white girls almost 2 kg more (Table VI). There is a link between superior physical development of children and improved socioeconomic status, better nutrition, improved health status and urbanization (477). However, within the South African context urbanization has only been shown to enhance physical development when it is accompanied by a corresponding increase in socioeconomic status (454). In this instance, the effects of ethnicity are likely to be confounded by socioeconomic status.

The flexibility of the children, as measured by the sit-and-reach test, was similar between the different ethnic groups within the sexes (Table XXIII). Corbin (478) states that flexibility is unrelated to body size and hence the differences in body size observed in this sample are unlikely to have been a large determinant in the outcome of this test. It is possible that any differences in Cormic Index between children resulting from differing maturity levels (45) may have affected their score on this test. However this index was not assessed within our study. As expected the girls displayed superior levels of flexibility to the boys in all age groups (333).

The sit-up test assesses muscular strength and endurance. Although as a group, the white boys always completed the most sit-ups in 30 seconds, the difference was marginal (Table XXV). Beunen (479) found that variations in strength depend largely on differences in stature and mass and hence physical maturity, within the preadolescent population. The performance of the different ethnic groups on this test, mirrors disparities observed in height and weight within the sample and could explain the differences.

The distance that a child could throw the cricket ball was a marker of a combination of motor co-ordination, muscle strength and power. Differences in the distance thrown by the boys started from 8 years of age, with the most superior performance from the white boys and the poorest performance from the black boys (Table XXVII). Among the group of girls, differences between the distances thrown by the girls in the cricket ball throw test only started from 10 years of age, where the black girls performed at a superior level compared to the white girls (Table XXVII). There was little difference noted between the mixed ancestry children and the other groups, with their scores falling between the other two ethnic groups in the majority of cases. A similarity between this test and the tests of muscle strength and endurance is evident among the boys, but surprisingly an opposite pattern is evident within the group of girls. Since this difference does not occur in the other strength and power tests, it is probable that there must be some form of training specific to upper body motor co-ordination within the group of black girls that is not present in the environment of their white counterparts.

Black boys and girls were slower than white and mixed ancestry children when completing the shuttle run in all age groups. This difference was significant in over half of the age groups observed (Table XXVI). Part of the differences observed may be accounted for by the anthropometric and nutritional differences mentioned previously. In schools from the poorest socioeconomic backgrounds informal interviews with the teachers revealed that some children had to walk 10 km or more to attend school. This suggests that some children may have been less motivated to perform well on this test in an attempt to conserve energy.

The legacy of apartheid has resulted in an uneven distribution of the different ethnic groups across the various socioeconomic levels within South Africa. More specifically, lower socioeconomic categories contain mainly black children, whereas white children are primarily concentrated within the highest socioeconomic strata. The fitness results of this study revealed that test performance according to ethnic group loosely followed the spread of ethnicity according to socioeconomic status. When McVeigh et al. (435) examined black and white children located in the Gauteng Province of South Africa, they noted that white children were more active, more likely to participate in physical education classes and watched less television than black children. They also pointed out that a combination of cultural and socioeconomic factors determined the total amount of physical activity in which a child participates. Where activity at school is insufficient, a parent or caregiver then becomes instrumental in encouraging physical activity. However, both cultural and socioeconomic circumstances will determine the degree to which physical activity may be facilitated in the home environment (435). In 2002 it was reported that less than one third of black children were offered formal physical education at school (16). Following this, revisions in the South African curriculum have led to the de-emphasis of physical education even further through its inclusion as a subsection of the life skills programme, rather than being maintained as a separate subject category. Informal interviews with teachers indicated that these policy changes have not affected the level of physical education offered in high socioeconomic status state schools, probably due to the greater availability of resources. This, when considered in conjunction with physical fitness scores, suggests a need for policy intervention within lower socioeconomic category schools in South Africa. However, the interpretation of the South African Discovery Vitality Health of the Nation data is incomplete without fully considering the socioeconomic background of these children. Therefore, further research should consider if differences exist between children of the same ethnic grouping, yet differing socioeconomic status; and children of similar socioeconomic status yet different ethnic group, within the South African context. This is discussed in Part 4: Socioeconomic Study.

The challenges and costs associated with testing large groups of children have resulted in limited availability of datasets for comparative purposes with other countries. Full age range datasets spanning 6 to 13 years of age, with large sample sizes are scarce, but exist for Belgium (480) and Zaire (presently known as Congo) (481). Partial datasets are also available for a number of European nations both developed ((378); (482); (483)) and emerging ((484); (462); (485); (486); (487); (488)).

When comparing the South African children to the data of another group of African children collected in Congo approximately 15 years prior to the present study, the Congolese children were up to 12 cm shorter and weighed 12 kg less. This was especially evident in the elder age groups and therefore indicative of possible nutritional deficiencies. Although South African children were slightly less flexible than those from the Congo, they performed better on the tests of muscular endurance (sit-ups) and power (standing broad jump). South African boys took considerably longer to complete the shuttle run test. The opposite occurred among the girls, although the difference was minimal. The Congo has a history of civil war and therefore it is possible that the majority of children tested in this nation may have lived under poor socioeconomic conditions and are likely to have also suffered from poor nutrition. These are all factors which could contribute to the differences in physical development and test scores observed.

Children from European countries in the late 1980s and 1990s tended to be slightly taller than South African boys and girls a decade later. Weight varied to a greater degree, although differences were not as large as those observed between the South African and Congolese children, rarely more than 9 cm in height and 6 kg in mass. With respect to European nations, the ethnic composition of the South African population may influence the observed difference, in which those of black African origin comprise almost 80%. The nutritional study showed that black South African boys and girls were significantly shorter and lighter than white children, with mixed ancestry children falling between the two groups. A more in depth study of differences in ethnicity and socioeconomic status within the South African population may be helpful in determining the degree to which ethnicity and socioeconomic status influence basic anthropometry among South African children and is considered later (Part 4:Socioeconomic Study).

South African boys had a slightly lower BMI and South African girls a slightly higher BMI overall, when compared to their European counterparts. Due to the void of data for younger age groups, comparisons mainly considered the elder age groups. In Section 5.2 it was noted that overweight and obesity levels, as measured by BMI-for-age cut-off points (13), tended to increase with age within the black girls. Black boys measured using the Cole et al. (13) criteria, had almost half the levels of overweight and obesity as black girls. These differences are likely to dominate the South African sample as black children are the predominant group within the South African paediatric population.

The sit-ups test showed the largest range in scores between the different European countries with all except Italian and Turkish boys outscoring South African children. European boys completed up to 6, and girls up to 8 more sit-ups, in the allotted time than their South African counterparts. The European children that outperformed the South Africans were both taller and heavier. Bouchard et al. (489) showed that height and body weight contribute the most to explained variance in sub-maximal work capacity. In children younger than ten years, height and weight explain 30-50% of variance. Over ten years of age, weight explains

10-25% of variance (310). Thus, the poor performance of South Africans may be explained by their lower height and mass for the equivalent chronological age.

Results of the standing long jump test showed that South African children were more powerful than all other nations barring Iceland. In both urban and rural areas many of the children in the moderate to low socioeconomic groups had to walk up to 10 km to attend school. It is probable that this time spent in commuting had a training effect on the muscles of the lower body.

South African and European children took a comparable amount of time to complete the shuttle run. Informal interviews with teachers revealed that many children from the lower socioeconomic strata came to school without having eaten in up to three days. Additionally, feeding schemes had been discontinued in many schools due to lack of funds. Therefore, as shuttles require a continuous rather than instantaneous effort, any training effect of commuting in this case was almost certainly tempered by the exertion of daily commuting and in some cases, lack of food.

Flexibility scores had the second largest range of mean scores for both genders. European children tended to have poorer levels of flexibility when compared to the South Africans, with the Italians having the lowest sit-and-reach scores. However, the Swiss children were consistently more flexible than South Africans in the older age groups. Studies have shown that higher BMI values do not influence flexibility (405). Additionally, Maes et al. (490) stated that varying levels of flexibility in pre-pubertal children may be largely explained by environmental differences. Both of these factors are likely to explain the large range in scores.

These results indicate that, with the exception of muscular endurance, South African children exhibit moderate to high levels of physical fitness with respect to European and other African children. Yet, the use of these results to make direct comparisons between different nations is limited by two main factors. Firstly, the datasets were collected by many different research groups which invariably increased the possibility of inconsistencies in test scoring. Secondly, these tests were conducted in different populations over a period of almost 20 years. Therefore, scores from children tested earlier in this time span are at an advantage when compared to children tested later, as a result of the secular deteriorations that have been noted in physical performance ((298); (299); (281)). Although, Tomkinson (491) did show that anaerobic fitness, more specifically speed and power, have remained relatively stable globally over the past forty years.

5.4 **Part 3: Interactions Study**

Studies have indicated that deficiencies and excesses in nutritional anthropometry may affect a child's physical fitness ((405); (410); (492); (493); (406); (463)). Suchomel (492) showed that children with lower levels of motor efficiency tended to have higher body weight and BMI values. While Prista et al., (410) noted that under-nourished children were disadvantaged on tests of strength but performed better on endurance tasks.

An overview of the interactions between the different variables showed weak correlations between the different tests of physical fitness (Table XXIX). Therefore, a composite fitness score was not a viable option for further analysis and results of each fitness test were considered separately.

The overweight and obese children had inferior performances when compared to the remainder of the sample on all tests of physical fitness barring the cricket ball throw (Figure 11). Obese children are disadvantaged in comparison to their normal weight counterparts when tasks incorporate the need to move their greater body mass against gravity (493). As such it is expected that they would not perform as well as the other children on the physical fitness tests which require the movement of the body through space such as the standing long jump, shuttle run and timed sit-up test. The cricket ball throw is a test of upper arm power and motor co-ordination in which the overweight or obese child is not disadvantaged by their excess weight, thereby explaining their ability to perform on par with the rest of the sample. However, the poorer performance noted on the sit-and-reach test is unusual as flexibility is normally not affected by nutritional status ((405); (494)). A possible explanation of this observation is that overweight and obese children in this sample are likely to be less active and therefore have had less exposure to flexibility enhancing activities.

The flexibility levels of all of the under-nourished children did not differ from the remainder of the sample (Figure 12 - Figure 15). Prista et al. (410) conducted a similar analysis on Mozambiquean children and also found no difference in flexibility scores between children of differing nutritional status. However, differences between the under-nourished groups and the rest of the sample were noted on the remaining tests of physical fitness. Trends were similar between the stunted and underweight groups, whereas trends in the wasted group tended to differ.

Although the mildly and moderately stunted children followed the same trends when compared to the rest of the sample, differences only reached significance in the standing long jump and cricket ball throw tests in the mildly stunted group (Figure 12 and Figure 13). The moderately stunted children performed significantly poorer than the non-stunted children on all of the tests of physical fitness barring the flexibility test, as previously noted. Underweight children were outperformed by the rest of the group on all but the shuttle run test, for which their performance did not differ (Figure 15). De Jonge et al. (463) noted that malnutrition and nutritional deprivation may cause structural, metabolic and functional changes in skeletal muscle. These changes manifest as a decrease in the size and numbers of fast-twitch muscle fibres, yet slow-twitch fibres are spared ((495); (496); (497)). This decrease would manifest as a reduced capacity to perform exercise tasks of relatively short duration as noted among the groups of stunted and underweight children. Underweight is a measure which is usually associated with acute lack and only used in children nine years and younger. The muscle tissue of these children may therefore not have been effected to as great a degree as that of the stunted children. This could explain why they did not suffer reduced capacity relative to the remainder of the group on all of the tasks.

The wasted group showed no difference in test performance when compared to the remainder of the group on all but the standing long jump and ball throw test (Figure 14). Although they threw the cricket ball a significantly shorter distance than the non-wasted children they were able to jump significantly farther. No obvious explanation for this difference in upper and lower body power was established. However, from this it may be concluded that tests of power are specific to the body part assessed, highlighting the need to be cautious when taking a single measure of power to represent the overall body power of a child.

Stunting during early life has been linked to excess weight gain in later years (188), resulting in a double burden of disease (8). Therefore, monitoring the relationship between the prevalence of stunting and overweight among children in countries in transition has been proposed as a useful tool to assess progress through the nutrition transition (10). A significant association between these factors was not evident in this sample. In fact, the non-stunted children tended towards higher levels of overweight and obesity than the mild and moderately stunted children for all comparisons (Figure 16). Jinabhai et al. (10) made a similar comparison with a sample of South African children from the mid 1990s and were also unable to find a significant link. However, they concluded that the very low levels of overweight and obesity among children within the sample indicated that South Africa was at an early stage of the nutritional transition. The prevalence of overweight and obesity in the present sample is much higher than that of the 1994 sample, but there has also been a concomitant decrease in the prevalence of stunting among young South Africans over the same time period. In addition to this, the co-prevalence of stunting and over-nutrition in the present sample is considerably lower than that of the 1994 sample. A similar trend was noted in Chilean children such that the strength of the association of overweight with stunting decreased as the prevalence of stunting declined in the population (22). This is expected as obesity is most strongly linked with increased stature, in populations of normal height (55). When considered in concert these factors indicate that South Africa may now have progressed to the later middle stage of the nutritional transition.

In conclusion, this study showed that barring the wasted group, young South Africans who were either over- or under-nourished were unable to perform on par with children who did not suffer from these nutritional disorders. Although some children suffered a double burden of disease evidenced as a co-prevalence of stunting and overweight, the prevalence of overweight and obesity in this group was lower than that of children from the general population. As the present youth will become the economically viable sector of the population in the future, it is necessary to consider methods to combat the underlying causes of impaired health-related fitness. Despite decreases in stunting prevalence of young South Africans over the past decade, it is still a problem among black children. An initial starting point to combat this may be for government to review their policies on feeding schemes, especially in schools where feeding schemes have been withdrawn due to lack of funding. An appeal to the private sector may be necessary to combat deficiencies in funding required to reinstate necessary feeding schemes.

However, as South Africa progresses through the nutritional transition a fine balance needs to be maintained such that supplemental feeding is not given to children at risk of becoming overweight or obese. With respect to the increasing prevalence of overweight and obesity associated with the nutritional transition, specific programmes targeting increased levels of physical activity among young South Africans need to be developed. Present government policies regarding physical education in schools should be reviewed with this in mind. Additionally, Section 7.4 in the Appendix of this thesis addresses the creation of a software package developed as part of this project, which has been designed to streamline the physical fitness testing process and assessment in South African schools. An on-line version of this software is due to be released by Discovery Vitality (Discovery Health, 16 Fredman Drive, Sandton, 2146) in 2009 in conjunction with a rewards programme. It is hoped that this will increase the interest and awareness of physical activity among South African school children.

5.5 Part 4: Socioeconomic Study

The anthropometric and physical fitness studies indicated that nutritional status and physical fitness test performance according to ethnic group, tended to conform to the differential spread of ethnicity according to the different socioeconomic strata in South Africa. The interactions study identified that over half of the differences noted between the ethnic groups was as a result of differences in socioeconomic status. Therefore, this study aimed to assess whether there were differences between the anthropometry, nutritional status and physical fitness of children of the same ethnicity yet different socioeconomic group. The effect of socioeconomic status was further investigated by assessing whether there were differences between children from different ethnic groups if they were positioned within the same socioeconomic class.

Black and mixed ancestry children from the lowest socioeconomic group were shorter than their counterparts from the highest socioeconomic group (Figure 17). Differences between the racial groups were not noted in the lowest socioeconomic class once differences in sample sizes had been considered. Among the highest socioeconomic group, differences were still evident between the different ethnic groups, however these were much less marked than the differences noted when socioeconomic class was not considered (Part 1: Nutritional Status Study). Similar findings were evident with respect to the masses of the children when classified according to ethnicity and socioeconomic group (Figure 18). Some studies have shown that children from a high socioeconomic status are taller and heavier than their low socioeconomic status counterparts and therefore these findings are as expected ((452); (435)). These differences between the socioeconomic groups may result from three different possibilities. Firstly, the exposure to an improved environment elicited by an elevated socioeconomic status may not have yet been of sufficient duration to result in the full growth potential being realised of the black and mixed ancestry children. Ellison and de Wet (498) suggest that increases in body size among South African school children may lag behind improvements in socioeconomic conditions. They support this observation by quoting the findings of two different studies. The first study examined secular trends in growth among both “favoured” and “oppressed” South Africans and the second assessed height- and weight-for-age scores of high socioeconomic status South African school children over the ten year period between 1989 to 1999 ((499); (500)). The former study found no increases in stature in any of the groups assessed (499). The later study reported that despite statistically significant increases in BMI and skinfold thickness, no differences were evident in the height- and weight-for-age scores over the decade in which assessment was carried out (500). Secondly, related to a possible lag in growth despite improvements in socioeconomic status, is the possibility that children presently classified in a high socioeconomic class may still suffer from an insult to growth experienced in early life. As stunting experienced early in life may result in lifelong short stature (27) this is a valid proposition. Finally, it is possible that ethnic differences do exist, with black and mixed ancestry South African children having a lower genetic potential for growth. However, this possibility will need to be examined by further research.

BMI values were significantly different between high and low socioeconomic status children, with the exception of mixed ancestry girls (Figure 19). No significant differences were evident between children of the lowest socioeconomic status category. In the highest socioeconomic category, black children had the highest BMI values. This is particularly interesting, as when socioeconomic status was not considered (Part 1: Nutritional Status Study), white children tended towards the highest BMI values. Further to this, black children of both genders had the highest prevalence of obesity among children from the highest socioeconomic group (Table XLIV and Table XLVIII). Although high socioeconomic status black children also had the highest prevalence of overweight among the girls (Table XLIII), white children had the highest overweight prevalence among the boys (Table XLII). When the prevalence of overweight and obesity among the high socioeconomic status children were considered together, black and white boys had similar levels of over-nutrition at 19.0% and 19.3% respectively. Mixed ancestry boys displayed a slightly lower prevalence of over-nutrition of 16.3%. Black girls had the highest prevalence of over-nutrition at 30.9%, whereas mixed ancestry and white girls displayed similar prevalence levels of over-nutrition of 19.2% and 20.6% respectively. Mixed ancestry children showed a relatively small difference between the overweight and obesity of children from the lowest and highest socioeconomic groups. However, black children from the highest socioeconomic group had an overweight and obesity prevalence double that of black children from the lowest socioeconomic group. Among the black adult population in South Africa overweight and obesity levels have increased with increases in urbanization ((62); (63)). In fact, the South African Demographic and Health Survey (3) identified that black women showed the highest levels of overweight and obesity in the South African adult population. The same survey showed that black men had the lowest prevalence of overweight and obesity. A similar pattern was noted among black South African teenagers, with 4.2% of boys, and 20.9% of girls classified as overweight (501).

However, the results of the present study indicate that black children of both genders had the highest BMI and obesity levels among young South Africans from the highest socioeconomic group. As it has been postulated that the origins of over-nutrition may start in childhood (61) affluent black males should be monitored as a group at risk for developing high levels of overweight and obesity, despite their historically low levels of over-nutrition. Overall, the difference between the prevalence of overweight and obesity among high and low socioeconomic status children needs to be addressed with urgency. Policies promoting physical activity and healthy eating among children from higher socioeconomic groups may be an initial method of addressing this problem.

The prevalence of mild stunting among high socioeconomic status children was approximately half that of low socioeconomic status children of the same ethnic group (Table XXXV and Table XXXIII). Moderate stunting was more than twice as high in the low socioeconomic groups when compared to high socioeconomic groups (Table XXXIV and Table XXXV). Although, this finding underlines the positive influence which improved socioeconomic status has on the prevalence of stunting, there are still considerable differences in the prevalence of stunting between the different ethnic groups in the highest socioeconomic category. The number of years which children have been exposed to improved socioeconomic conditions may alter the degree to which they are able to recover from the insult of a less privileged childhood. As previously noted, children who develop stunting during the first few years of life, will often display short stature for the rest of their lives (27). Thus children who experienced a sudden elevation in socioeconomic class may still retain some of the adverse effects of their childhood. This hypothesis is supported by Ellison and de Wet (498) who proposed that South African schoolchildren may experience a lag in positive increases in stature, despite improvements in socioeconomic status.

An interesting finding was that although a lower prevalence of wasting among the highest socioeconomic status boys within the same ethnic group was observed (Table XXXVI), high socioeconomic status mixed ancestry girls (Table XXXVII) had twice the prevalence of wasting than their low socioeconomic status counterparts. White girls in the highest socioeconomic group displayed higher levels of wasting than both the black and mixed ancestry girls in the lowest socioeconomic category, and the prevalence of wasting among high socioeconomic status black girls was only slightly lower than that of low socioeconomic status black girls. This phenomenon of a generally higher prevalence of wasting among girls of high socioeconomic status is not unique to South African children. Prista et al. (410) noted a higher prevalence of wasting among Mozambiquean girls from high social class, although they were unable to offer an explanation for this finding. Trends similar to those noted for wasting were also evident in the prevalence of underweight among girls of mixed ancestry (Table XLI). The co-prevalence of moderate stunting and wasting was very low among all of the groups (Table XXXVIII and Table XXXIX).

There was little difference between the sit-and-reach scores of the high versus low socioeconomic status children (Figure 20). This finding is in contrast to the results from other studies which have shown that children from high socioeconomic status tend to have poorer flexibility than those children from low socioeconomic status ((455); (456); (502)). However, the relatively small number of children in the high socioeconomic status group may have resulted in insufficient power to detect a significant difference.

High socioeconomic status children generally out performed the low socioeconomic status children on the standing long jump (Figure 21). Freitas et al. (455) noted that high socioeconomic status girls outperformed low socioeconomic status girls in the standing long jump test, with the opposite reported among the boys. However, in contrast to this, Renson et al. (503) reported greater explosive power in upper class boys. A study considering low and high socioeconomic status mixed ancestry South African children who had been matched for height, found that the low socioeconomic status children had considerably weaker muscles (504). As the standing long jump test relies on the explosive power and strength of the muscles, impaired muscular development in the lower socioeconomic group is a likely cause of the observed differences.

Children from the high socioeconomic status group tended to perform better on the sit-up test than those from low socioeconomic status group (Figure 22). Similar results were observed in two other studies ((455); (456)). As noted for the standing long jump test, differences in muscular strength seem the most likely cause of this finding. When considering whether differences existed between children of the same socioeconomic status, black high socioeconomic status girls performed significantly fewer sit-ups in the allotted time when compared to the mixed ancestry and white high socioeconomic status girls. The sit-up test requires the child to lift their trunk against gravity. Pongprapai et al. (493) stated that obese and overweight children are disadvantaged when compared to normal weight children in tasks requiring the movement of the body weight against gravity. Therefore the considerably higher prevalence of obesity and overweight among the high socioeconomic status black girls may explain this finding.

Little difference was noted between the shuttle run test scores of children from high and low socioeconomic status, with the exception of black boys (Figure 23). Previous studies have shown that high socioeconomic status children performed better on the shuttle run test than low socioeconomic status children ((455); (456);

(505)). In the present sample the black boys mirrored this finding. However, the performance of the other groups was dependant on age with low socioeconomic status children tending towards better performance in the younger age groups and high socioeconomic status children performing better in the elder age groups. These trends may hint towards a slow accumulation of adverse effects on children's physical fitness with increased length of exposure to a poor socioeconomic environment.

Differences between the cricket ball throw scores of the different socioeconomic groups were small with no consistent trends across all of the age groups for ethnicity or gender (Figure 24). However, significant differences were noted between children from different ethnic groups but the same socioeconomic group. As the cricket ball throw is an upper limb activity it is less likely to be affected by differences in overweight status. Throwing is a "motor skill" and may be improved with practice (506), therefore different levels of exposure to this task resulting from different cultural norms may explain these differences to some degree.

When matched for ethnicity, children living in privileged environments in South Africa tended to be taller, weigh more, have higher BMI's and a higher prevalence of overweight and obesity when compared to those from poor environments. Children from poor socioeconomic areas also showed higher levels of mild and moderate stunting. Additionally, high socioeconomic status children usually performed better on tests of physical fitness than low socioeconomic status children from the same ethnic group. However, children from different ethnic groups, yet the same socioeconomic group, did not always display the same values for anthropometric and physical fitness levels. As South Africa is in the process of recovering from the racial inequalities of past legislation, these differences may not be solely attributed to ethnic differences. Further studies will need to consider these differences in greater detail as it may take a longer time for children placed in a more privileged environment to experience the full benefits of their elevation in socioeconomic status.

5.6 **Conclusions**

A summary of the main conclusions from this thesis follows. These conclusions are again separated according to the four different sections of this thesis.

5.6.1 **Part 1: Nutritional Status Study**

Differences were noted in the levels of the different indicators of under-nutrition between the ethnic groups. Black children had the highest levels of mild stunting and moderate stunting, whereas white children displayed the lowest levels for these indicators. Boys and girls of mixed ancestry showed the highest levels of wasting and white children had the lowest levels of underweight among the different ethnic groups. Co-prevalence of stunting and wasting was low in all of the groups. It is encouraging to note that there has been a decrease in the prevalence of the majority of conditions associated with nutritional lack over the decade preceding this study. However, as levels of stunting are still elevated above the reference population norms in some ethnic groups, the current policy on feeding schemes should be reviewed. Strategic placement of intervention programmes would benefit children still at risk of stunting, wasting and underweight.

An analysis of secular trends showed considerable decreases in the prevalence of mild stunting, moderate stunting, and underweight prevalence occurring over the decade preceding the current study. Little difference was noted in the levels of wasting. However, there has been an alarming increase in the prevalence of overweight and obesity among young South Africans. Further to this, South African children in this sample show levels of overweight and obesity similar to the international trends in developed countries of a decade ago. With increased urbanization there is a need to assess the influences of modern society within the South African context, in order to introduce suitable interventions. The differences observed between the ethnic groupings suggest that it may be necessary to introduce different intervention strategies for different groupings. These results even suggest that different intervention strategies for the different genders within ethnic groups should be considered (for example within the group of black children). As a result of apartheid the majority of children falling into the least privileged groups were of black and mixed ancestry, whereas children from all ethnic groups were included in the more privileged groups. Further investigation is therefore necessary to identify whether targeted intervention strategies need to focus to a greater degree on ethnic or socioeconomic differences.

5.6.2 **Part 2: Physical Fitness Study**

In the majority of cases the measurements of fitness in the black children were the lowest and the white children the highest. The scores of the mixed ancestry children usually were between the other two groups. Exceptions to this were the flexibility test, where results were similar between the ethnic groups and cricket ball throw, where black girls displayed a superior performance as they became older. Whether socioeconomic differences are a large factor leading to the differences in the fitness test scores between the different ethnic groups needs to be investigated further. These results highlight the need to reconsider policy with respect to formal physical education classes within state schools in South Africa, especially those schools in which black children predominate.

Current South African children achieved considerably higher scores than Congolese children had 15 years previously, on most tests, with exceptions in the flexibility of both genders and the shuttle run scores of the boys. When compared to both developed and emerging European nations, South African children had superior levels of flexibility in many cases, and were able to jump and throw further than all other nations barring Iceland. Muscular endurance, as tested in the form of timed sit-ups, was consistently inferior in the South African children, while little variation was evident between levels of speed and agility. South African children show moderate to high levels of health-related fitness with respect to other nations. However, interventions should consider the consistently inferior muscular endurance of South African children.

5.6.3 **Part 3: Interactions Study**

Overweight and obese children performed poorer than the remainder of the group on all physical fitness tasks barring the cricket ball throw. This implies a need to focus on the promotion of physical activity in schools and national programmes to encourage activity and physical fitness. Stunted, wasted and underweight children also showed impaired levels of physical performance on a number of the tests of physical fitness. Thus, feeding schemes and other targeted interventions may be of use in these groups.

As the present youth will become the economically viable sector of the population in the future, it is necessary to consider methods to combat the underlying causes of impaired health-related fitness. The findings from this study imply that South Africa is in the later middle stage of a nutritional transition and therefore needs to use a duel approach, targeting both the under-nourished and overweight. Therefore, policies should be developed and implemented which target both over- and under-nutrition among young South Africans.

5.6.4 **Part 4: Socioeconomic Study**

Despite ten years of democracy in South Africa there are still some imbalances in the nutritional status and physical fitness levels of children from different ethnic groups. Children from lower socioeconomic status are at a greater disadvantage with respect to under-nutrition, which has been associated with a lower physical fitness capacity. At the other end of the scale, children from high socioeconomic status schools show high levels of overweight and obesity which has also been associated with compromised physical fitness test performance. These disparities between the ethnic groups imply the need for different interventions programmes for different ethnic and socioeconomic status groups. Interventions targeted at feeding schemes and physical activity should be the main focus for low socioeconomic status children in South Africa, whereas interventions focused on decreasing the levels of overweight would be of benefit among children from a high socioeconomic status.

5.6.5 **Final Conclusions**

Together the studies that comprise this thesis demonstrate how the legacy of apartheid has left its mark on the anthropometry, nutritional status and health-related fitness of South African children. The findings regarding secular changes in nutritional status are positive with respect to under-nutrition, yet there are still large disparities between the prevalence rates in the different ethnic groups. As such, the presence of feeding schemes in low socioeconomic status schools is still necessary. On the other hand, overweight and obesity is rapidly becoming a problem among young South Africans and government policies such as the lack of physical activity offered in public schools should be reviewed to ameliorate this increase before it reaches epidemic proportions.

5.6.6 **Limitations**

The studies in this thesis have some limitations which should be noted. Primarily there is an uneven spread of children from the different ethnic groups across the socioeconomic strata. As this is a result of historical South African legislation, little could be done to rectify this imbalance in the sample while concurrently maintaining random sampling.

Due to the logistics required for a specific measure of socioeconomic status for each child in such a large sample, the socioeconomic status of the school attended by each child was used as a proxy of their individual socioeconomic status. Although sufficient for an epidemiological study such as that discussed in this dissertation, this loose assignment of socioeconomic status may have resulted in the misclassification of some children. For example, some of the black and mixed ancestry children in the highest socioeconomic schools may be scholarship students and thus still be exposed to poor conditions at home.

Finally, due to the large sample size of this study, logistical constraints necessitated the omission of some measures of physical fitness. In particular , the test battery does not include a direct measure of cardiorespiratory endurance which therefore limits the interpretation of health related fitness.

Despite these limitations, this thesis has important and novel practical implications regarding the cause of perceived anthropometric, nutritional and health-related fitness differences between the ethnic and socioeconomic groups in South Africa.

5.6.7 **Future Research and Direction**

Based on the findings of this thesis, it is recommended that future research probe more deeply into the interactions between socioeconomic status and ethnicity and their effects on nutritional status and physical fitness outcomes. To address this question more fully, a selective sampling approach should be used to ensure that children from each ethnic and socioeconomic group are well represented. Additionally, an individual measure of socioeconomic status based on a household assets ratio would increase the precision of classification according to socioeconomic status. The possibility that a portion of the differences still evident between the different ethnic groups when compared at the highest socioeconomic level could have resulted from differences in genetic potential for growth should also be explored.

As South Africa continues to recover from the inequalities of the past it will be important to continue monitoring secular changes in the nutritional status and health-related fitness of young South Africans. It is hoped that the introduction of the Vitality Schools fitness testing programme scheduled to be launched during the 2009 school year will facilitate this in the future.

CHAPTER 6

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CHAPTER 7

APPENDICES

7.1 **Appendix A: Informed Consent**

CHILD FITNESS CONSENT FORM

RE: Permission to test the physical fitness levels of school children in grades 1 to 7.

Dear parent / guardian

The University of Cape Town and the Medical Research Council of Chronic Diseases of Lifestyle Unit is doing a study concerning the “physical fitness levels” of South African primary school children.

Your school has been randomly selected from schools in South Africa and therefore your child is invited to participate in our study.
We will be using trained field workers from ‘Sporting Chance’ to conduct the fitness tests with the children. The fitness tests include standing long jump, ten times 5-metre shuttle run, sit-ups in 30 seconds, cricket ball throw and sit and reach flexibility test. In addition, we will be assessing weight, height, age, gender, ethnicity, the language spoken and the number of people living at home at present. Fitness tests will be carried out during a physical education or life-skills lesson and may all be conducted in ordinary PT clothes. Your child will not be expected to do anything that would not be required during a normal PT class. He/she will be able to warm up and will be well supervised. All the information obtained will be processed confidentially without revealing the identity of the child.

All children must have written permission from parents or caregivers before they can participate in the study. If interested, please sign the form consenting for your child to participate in our study. Your child will be given feedback concerning their fitness levels and a small gift for their participation. Participation in this study will provide information to assist policy makers within the South African government.

Thanking you

Prof. M. Lambert
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Department of Human Biology
University of Cape Town
021-650-4558

Ms Miranda Armstrong
UCT/MRC Research Unit
Department of Human Biology
University of Cape Town
0845780745

Please sign below to provide consent for your child to participate in the study.

I ………………………………………………………………… (name of parent or legal guardian) give informed consent on behalf of my child ………………………………………….. (name of the child) to participate in the above-mentioned study. I have read and fully understand the information about the study.

Be informed that you are free to withdraw at any time from the study, without prejudice, if you wish to do so.

Signature of Parent or guardian: **Date:**

………………………………….. ……………………………………..

Witness: **Date:**

………………………………….. …………………………………

KINDER FIKSHEIDS TOESTEMMINGSVORM

“RE”: Toestemming om die fiksheidsvlakke van kinders in graad 1 tot 7 te toets

Geagte ouer/voog

Die Universiteit van Kaapstad, in samewerking met die Mediese Navorsings Raad se Eenheid vir Kroniese Siektes van Lewenstyl, is tans besig om ‘n studie te doen rakende die fisieke fiksheidsvlakke van Suid-Afrikaanse laerskool kinders. U kind se skool is ewekansig geselekteer uit Suid-Afrikaanse skole en daarom word u kind uitgenooi om aan die studie deel te neem.

Opgeleide veldwerkers van die organisasie ‘Sporting Chance’ gaan die fiksheidstoetse uitvoer. Die fiksheidstoets sluit in ‘n sprong vanuit ‘n staande posisie, tien maal 5-meter naellope, opsitte vir 30 sekondes, krieketbal gooi asook ‘n sit en strek soepelheidstoets. Verder gaan ons ook inligting omtrent u kind se massa, lengte, ouderdom, geslag, ras, taal voorkeur en hoeveelheid mense wat op die huidige oomblik in u huishouding woon, insamel. Die fiksheidstoetse sal tydens die liggaams opvoeding of lewensvaardigheidsklasse gedoen word in gewone LO klere. Daar sal nie van u kind verwag word om enige iets te doen wat hy/sy nie gewoonlik in die LO klas doen nie. U kind sal die geleentheid gegun word om op te warm voor die toets en sal ten alle tye onder toesig wees. Alle inligting sal vertroulik geprosesseer word sonder om die identiteit van die kind bekend te maak.

Alle kinders moet skriftelike toestemming van hulle ouers/voog verkry voordat hulle aan die studie kan deelneem. Indien u instem dat u kind aan die studie deelneem, teken asb die toestemmingsvorm. U kind sal terugvoer ontvang oor sy/haar fiksheidsvlak en sal ook ‘n klein geskenkie ontvang vir deelname aan die studie. Deelname aan die studie voorsien inligting aan beleidvormers in die Suid-Afrikaanse regering.

Byvoorbaat dank

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Teken asb die aangehegte vorm om toestemming te verleen vir u kind se deelmane aan die studie.

Ek, ……………………………………………….(naam van ouer of regtelike voog) gee hiermee toestemming sodat my kind,……………………………… (naam van kind) aan die bogenoemde studie mag deelneem. Ek het die ingeligte toestemmingsvorm gelees en verstaan ten volle die informasie rakende die studie.

Ek verstaan ook dat, indien sou ek wou, ek enige tyd my kind kan onttrek van die studie sonder enige bevooroordeling.

Handtekening van ouer of voog: **Datum**:

……………………………………. ……………………………….

Getuie: **Datum:**

……………………………………. ………………………………..

7.2 Appendix B: Form used to record scores for each child

NAME:				**B W C I O**
GENDER:	**male**	**female**		**AGE:**
HEIGHT (cm):			**WEIGHT (kg):**	
SIT AND REACH ***best of 2***	**1.**			**2.**
SIT UPS (no. in 30 sec)				
STANDING LONG JUMP (cm) ***best of 2***	**1.**			**2.**
SHUTTLE RUN (sec)				
CRICKET BALL THROW (m) ***best of 2***	**1.**			**2.**

7.3 Appendix C: Examples of schools evaluation forms

School name	Grey – Port Elizabeth		Date	/08/04
	Surface	Number	Adjacent	Outside/in
Sit ups	School hall, wooden floor	In pairs	Yes	Inside
Height and weight	Against wall in hall	Two	Yes	Inside
Sit and reach	Against wall, in hall	Two	Yes	Inside
Standing long jump	On wooden floor	Three	Yes	Inside
Shuttles	On wooden floor	Three	Yes	Inside
Cricket ball throw	Well manicured, flat, grass field. Minimal wind	Three	Yes	Outside
School buildings	Well manicured			
Sport facilities	Well kept, flat fields.			
Uniforms	All children had full uniforms and sports kits			
Tuckshop	Commercial.			
Comments	They have PT classes in the curriculum. The children were poorly behaved			
Number tested	292			
Level of school	5			

School name	Papenkuil – Port Elizabeth		Date	/08/04
	Surface	Number	Adjacent	Outside/in
Sit ups	On concrete	Pairs	Yes	Outside
Height and weight	Concrete, against wall	Two	Yes	Outside
Sit and reach	Concrete, against wall	Two	Yes	Outside
Standing long jump	Concrete surface	Three	Yes	Outside
Shuttles	Concrete surface	Three	Yes	Outside
Cricket ball throw	Field, rough surface. Throwing in different directions on the two different fields. There was wind.	Two, One	No	Outside
School buildings	Not manicured, except one small grass, garden area			
Sport facilities	Two fields, poor condition. Basket ball court			
Uniforms	Most children had school uniform and gym kit			
Tuckshop	Commercial			
Comments	The Morning live crew came this day. Children better behaved then yesterday. Mostly mixed ancestry and black children.			
Number tested	283			
Level of school	4			

7.4 **Appendix D: Software**

7.4.1 **Literature Review**

7.4.1.1 **Introduction**

This section aims to provide a brief overview of software development. It starts with an introduction to software and its use as a tool to aid humans in the performance of various tasks. An outline of three of the most commonly used approaches to software development follows. Methods for planning a new software development project and the choice of an appropriate programming language are then considered. Finally, widely accepted principals of good screen and report design are introduced to the reader.

A computer is as useful as its ability to impact on activities that are of importance, benefit or interest to people. It may only have an impact if it is able to effectively communicate with both the people and machines which use it (507). This may be summarised as follows, *'Communication is the exchange of messages with some permissible content within some context to produce a conversation'* (507). Some of these terms require further definition. Exchanges refer to data or instructions sent to the computer followed by a response from the computer. Each exchange needs to elicit an appropriate response such as the movement to a different menu or item. Context denotes the environment which provides meaning for an exchange. For example, a question asked by the computer would give meaning to the instruction of yes or no. Permissible content is concerned with the provision of instructions which are allowable in a specific exchange. In some contexts a yes/no answer is appropriate, in others a numeric answer would be the correct response. Conversation indicates a succession of exchanges which together accomplish a given process within the environment of the application (507).

An exhaustive review of software design would be inappropriate and unnecessary for the understanding of the software developed as part of this dissertation. As such, a review of only the most pertinent aspects of software design follows.

7.4.1.2 **Purposes of information technology and automation**

Information technologies are designed to improve efficiency or effectiveness. Efficiency is defined as completing tasks correctly, for example the automation of routine, paper-based processing tasks. Effectiveness refers to completing the assigned task correctly. This is concerned with streamlining and avoiding unnecessary tasks (508). Thus, a main advantage of automation is the simplification of the tasks required by the user and the reduction of human input in tasks where no decision making is required (509). Software should equip the user to avoid handling routine, tedious and error-prone processes, while allowing the individual to devote more time to planning, decision making and dealing with unexpected situations (510). In many sectors automation has resulted in an increase in flexibility and the types of services offered. Other advantages include the storage of records electronically, increased productivity and a reduction in costs (511).

A common application of information systems is databasing. This is concerned with the storage, processing and retrieval of data. The processing step may include a complex combination of automated mathematical and/or logical operations which would otherwise have been completed manually (509).

7.4.1.3 **The Software Development Lifecycle**

A software development ‘lifecycle model’ is a model which describes a group of activities and how they are linked to each other. The popularity of these development models stems from the ease by which progress may be tracked, deliverables specified, resources assigned and goals set. Currently recognised software development models vary in their level of complexity and sophistication. The size and intricacy of the project will determine the appropriate development method. There are three main software development lifecycle models which are representative of commercially used models and have a proven track record (512).

7.4.1.3.1 **The Waterfall Lifecycle Model**

The Waterfall model, put forward in the 1970's, was the first formalised approach to software development and forms the basis of most methods currently in use (Figure 25). This model is linear and depends on the completion of the preceding step before initiation of the next step. Over time this model has evolved, resulting in a lack of uniformity on the precise names given to each step. However, the lifecycle generally starts with requirements analysis, followed by design, then coding, implementation, testing, and concludes with maintenance (512).

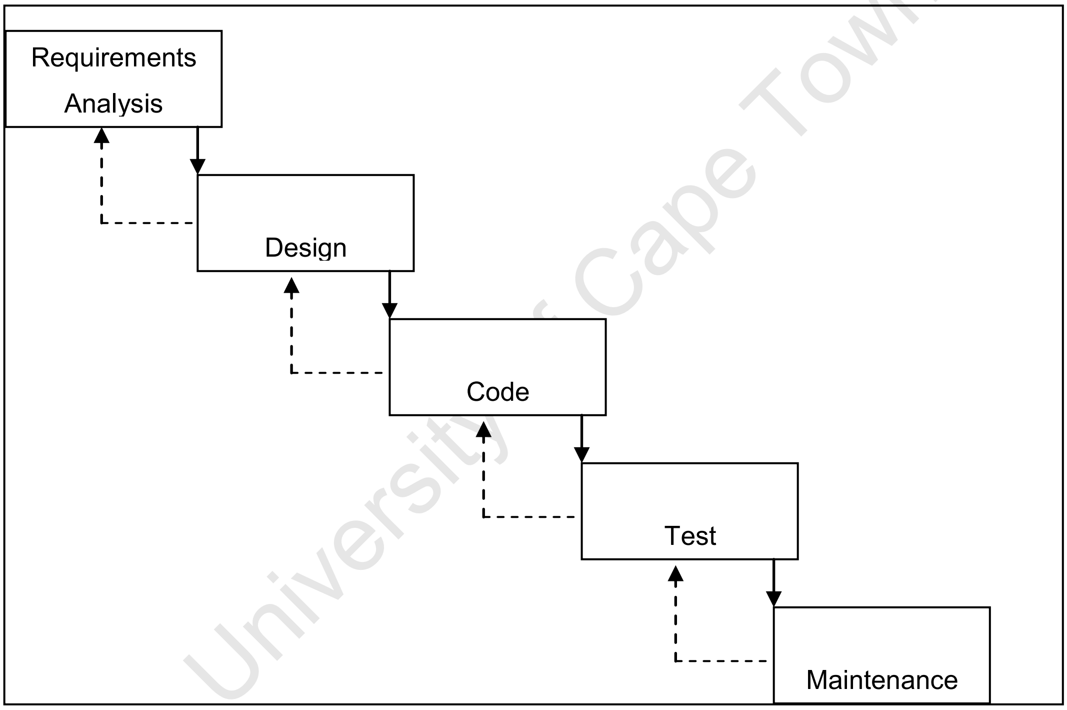


Figure 25: The waterfall lifecycle model of software development (adapted from (512) and (513)).

There are two main advantages of this method. Firstly, before progression to each new stage, the product can be checked to ensure that it conforms to the requirements of the client/project goals (validation) and that it correctly and consistently captures the specifications of the previous stage (verification).

Secondly, the task of project management is simplified as the step-wise approach encourages adherence to the proposed schedule and checkpoints (511).

The main limitation of this method is that changes in the system requirements often occur over time (512). This is exacerbated by the inability of the programmer to gain a full understanding of the user requirements before a substantial amount of the design has been completed (511). Further to this, the waterfall model, as originally described, does not allow for the revisiting of already completed steps. Yet, current users of this method tend to employ a more flexible approach with the incorporation of iteration and review meetings (512).

7.4.1.3.2 **The Spiral Lifecycle Model**

Boehm and Belz (514) proposed the Spiral lifecycle model of software development in 1988 (Figure 26). This method employs an iterative approach with ideas and progress frequently assessed through risk analysis and prototyping. Consecutive iterations may originate from different lifecycle models. At its core it promotes considering alternative approaches and revisiting any steps during which problems have occurred. It was initially developed as an attempt to recognize and manage risks during the design process (512). The main drawback of this model is a lack of management control. More specifically, concerns relate to whether repeated prototyping will result ultimately in delayed delivery or even an inability to complete the final system (511).

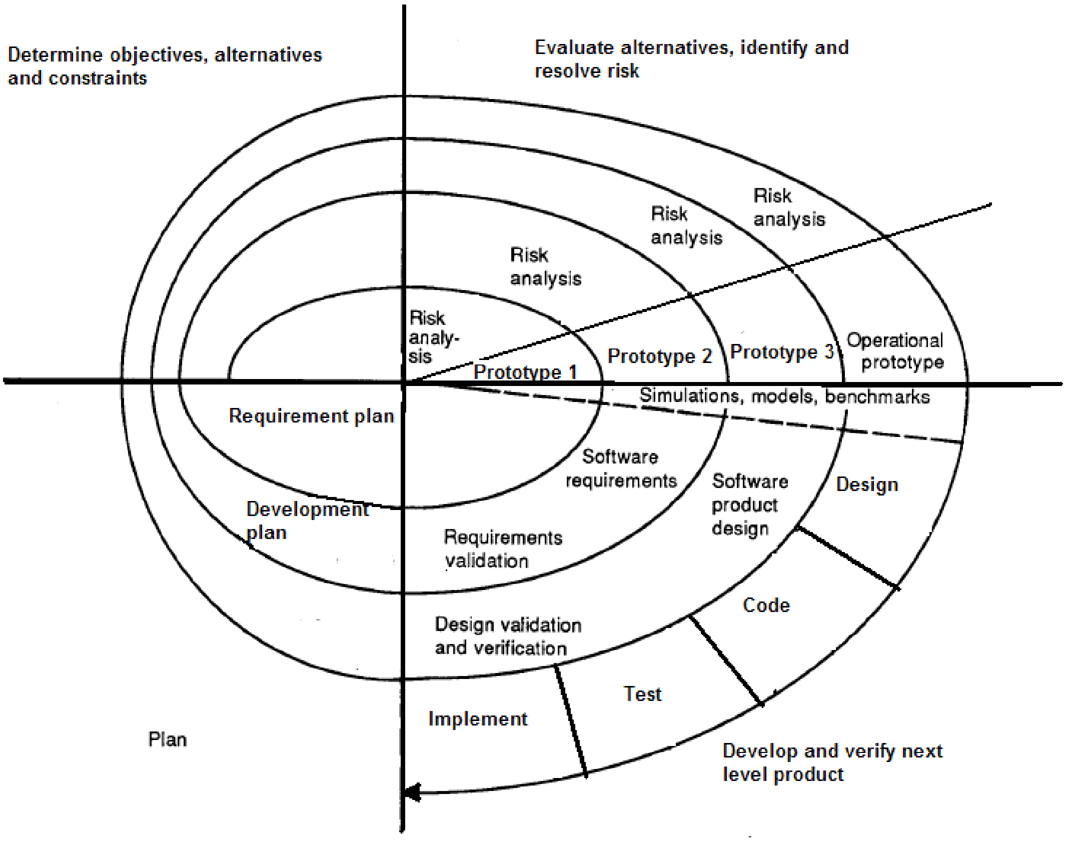


Figure 26: The Spiral lifecycle model of software development (adapted from (512)).

7.4.1.3.3 The Rapid Application Development (RAD) Model

During the past two decades there has been an increased focus on the users during the software development process. Rapid Application Development adopts a user-centred approach enabling increased control of the risks which often result from requirement changes during software development. One of the key concepts of RAD is time-boxing. This is the use of bi-annual time-limited cycles, following which a full system or a working partial system is delivered. The project is thus broken down into a number of smaller projects, encouraging incremental development and flexibility (512). Another key concept is Joint Application Development (JAD) Workshops. These sessions are characterised by both the developers and users meeting to determine system requirements. RAD has five recognised phases, starting with the project set-up, moving onto JAD workshops, then iterative design and build, followed by the testing of the final prototype and terminating with an implementation review (Figure 27) ((512); (515)).

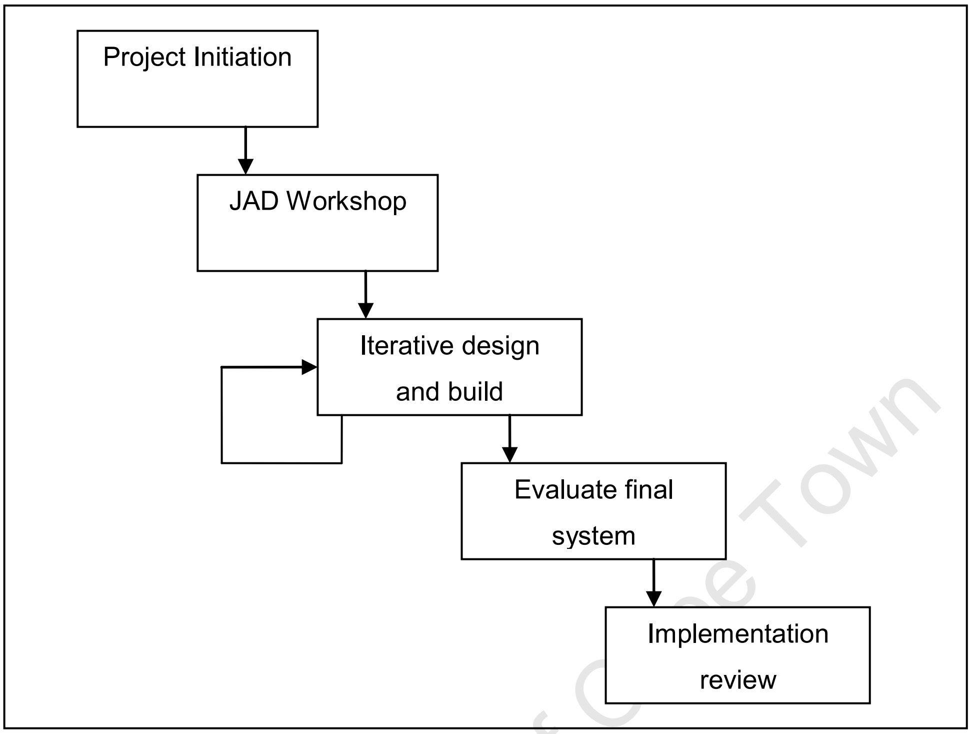


Figure 27: The Rapid Applications Development lifecycle model of software development (adapted from (512)).

7.4.1.3.4 Choosing an appropriate systems development lifecycle method for use in the creation of the health-related fitness testing software package

The structure of this project meant that initially there were few stakeholders in the development of the software, namely: the PhD student researcher and her two supervisors from the University of Cape Town. Further to this, the PhD student researcher working on the Health of the Nation project was also the software programmer and hence the initial user of the software. Yet, it was still necessary to create software which could in the long term be utilised by non-expert users, for example physical education teachers in schools across South Africa.

The RAD model was deemed unsuitable for use in the given scenario owing to the limited number of stakeholders involved in the project. Although the spiral lifecycle model was a viable option the concept of multiple prototyping was deemed to be tedious and unnecessary. As the individual providing the system requirements and specifications was also the system developer, this overcame the main drawbacks of the waterfall model, particularly when the flexibility of the more recent descriptions of this model was considered. Therefore, the waterfall model for systems development was chosen as the most appropriate development lifecycle for the development of a software system suitable for use in the processing, profiling and ranking of the health-related fitness characteristics of primary school children according to South African normative data. However, as neither the RAD nor spiral models were used in the software development it was necessary to ensure that the system was still user friendly. This was achieved during the development process, through the inclusion of the principals of good screen and report design as discussed later in this chapter.

7.4.1.4 **Systems analysis and design**

Systems analysis is the process of understanding and describing in detail the requirements of the system, whereas systems design refers to the detailed description of how the components comprising the system should actually be put into operation (516). Initially, the developer needs to gain an understanding of the requirements of the system. Usually, this high-level list is developed in conjunction with the stakeholders of the project (511). These requirements are then expanded and developed into a blueprint for the construction of the software (513).

7.4.1.4.1 **Data volumes**

In order to best match the design of the software to the available hardware a basic idea of the expected volume of data processing and throughput is required. The optimal response times should also be considered (513). If shorter response times are required it may have an impact on whether for example, frequently used equations are located in a database or hard coded into the software. Miller (517) described three psychological threshold levels of human attention. Users perceive a response time of one tenth of a second as instantaneous. One second response times allow the user to feel that they are able to interact freely with the computer. However, if latency exceeds ten seconds the user tends to lose focus on the dialogue box. More recently, Bouch et al. (518) examined internet response times. They confirmed the earlier findings of Miller (517) by concluding that perceived quality of performance dropped-off if latency was longer than eight to ten seconds.

7.4.1.4.2 **Data Modelling**

Data modelling serves to provide an understandable, accurate and precise method for expressing the information structures of the required system. Further to this, it supplies a uniform grounding from which system developers are able to move from the analysis, through design and to the implementation phase of software development. Data models are constructed using attributes, data entities and relationships (519).

Attributes are the simplest portions of data which are of interest in a software application (519). When these are grouped together to create more complex components they are referred to as data entities. Based on the understanding of the developer of the system, an assessment of the key interactions between these components is used to identify relationships (511).

These components are usually used to construct an entity relationship diagram showing each data entity and its relationship to other data entities. This process is used to view the requirements of the system in terms of the data components only and aids in gaining an understanding of the overall system (513).

7.4.1.4.3 **Process Modelling**

Structured software process modelling is concerned with describing what processes occur in the system and what actions it should be able to perform (519). Central to this is the concept of data flows, described as groups of data moving and flowing through a system. This concept includes an indication of both the source and destination of each flow (515). Two methods are useful for modelling these interactions, namely lists of inputs and outputs, and data flow diagrams (519).

7.4.1.4.3.1 Inputs and Outputs

A list of inputs and outputs indicates how data entities are related to the functionality of the software (513). Inputs may include the recording and entering of data as well as the issuing of instructions to the computer system. Outputs are concerned with providing information to the user regarding the current state of the system information which they have requested (511). A diagram including two separate lists, one for major inputs, and the other for major outputs is often used in this step. In data processing systems the inputs are often closely related to the database design, whereas outputs are usually displayed on the screen or produced as a physical printout (513).

7.4.1.4.3.2 Functional Requirements and Data flow diagrams

The functional requirements relate to what the software system is required to do and encompasses the actions of both the software and the human user. These requirements are documented in the form of a functional specification which has a hierarchical structure. The top level is more abstract and comprises basic descriptions of the main functions of the system. The bottom level describes in specific detail how top level functions are to be achieved (511) and often becomes the basis of separate modules of computer code (513).

The most commonly used tool in diagramming the functional requirements of a system are data flow diagrams. These diagrams are concerned with the processes occurring in the system rather than emphasising the data structures. The diagrams aim to represent the flow of data between external entities and processes, and between processes and data stores. Data flows represent transitory data, whereas data stores represent data which persists (519).

7.4.1.5 **Choosing a suitable programming language**

Laudon et al., (520) said that the kind of problem being solved will impact on the choice of programming language. Some languages are better suited to the development of software for specific purposes such as database, scientific or business applications. The hardware resources available and the degree of portability required may determine the language choice. The programming languages with which the software developer is familiar and the ease with which they may be able to learn a new language will also have a bearing on the choice of the programming language. If maintenance by a person other than the original programmer is expected, a well-known language should be used. Finally, the urgency with which the application is required often determines the final choice of programming language.

7.4.1.6 **Screen Design**

A good screen design decreases the complexity of the interface *'as perceived by the user'*. The screen and associated input devices (keyboard and mouse) allow the user to communicate with the computer through the form of an interactive dialog. This dialog is ruled by both semantic and syntactic rules (507). Semantic rules establish the meaning of different components of the interface (507) and are described as mental models of the major objects, actions and locations in the system (521). Correct syntax controls the order of components (507) and the rules for combining them (521). When related to database systems, the four primary purposes of screens include: data entry, data updating, data deletion and data inquiries (507). Explanations follow for a number of accepted concepts which contribute to a simple, easy to navigate graphical user interface (GUI) (507).

7.4.1.6.1 **Concreteness**

Humans are better able to process concrete objects than abstract concepts. Within the context of software, a person finds learning to use an icon (a visual representation of an object) simpler than the same concept represented by an abstract idea (507). In some cases concepts are abstract and hence the mapping between an icon and the concept are more difficult. However, once the meanings of the icons are initially learnt they are readily remembered (511).

7.4.1.6.2 **Visibility**

As a result of their relatively poor memories, people find it hard to remember options which are not readily visible; consequently, the developer should strive to reduce the short-term memory load of the user (509). Focusing on humans' well developed abilities in pattern recognition may overcome this shortfall. Humans find it is relatively simple to select from a list of options and therefore options, commands, prompts and help options should be visible on screen. The inclusion of drop down lists from which the user may select options is also good practice ((507); (522); (511)).

7.4.1.6.3 **Modifiability**

It requires less effort to alter a template or partially filled in input field. Consequently, in viable instances, a default value should be included in an input field. The user is then prompted about acceptable input values and formats. In instances where the default value is correct, effort is deceased further as the user need only accept the value provided (507).

7.4.1.6.4 **Interaction**

Appropriate system feedback from the computer software following an input by the user is important (523). As such, interactive interfaces in which records are entered separately as opposed to a batch processing approach tend to be more effective. In this setup, the data in each field may be checked on entry, and feedback provided as required. This method also tends to make fewer demands on short-term memory. On the other hand, batch entry expects the user to enter multiple records without feedback. Frequently, this results in the perpetuation of errors between records (507).

7.4.1.6.5 **Familiar conceptual model**

Well-known prototypes and metaphors are simpler to use and understand than new models ((524); (525)). For example, the 'real-world' office concept of a desktop with documents has been adapted to the 'virtual-world' computer environment. This idea was initially introduced by Xerox (526) but is now widely used by other operating systems and software developers. Within the context of database applications, using an interactive form to input and update data is much easier than using literal instructions as required by command based languages (507).

7.4.1.6.6 **Consistency**

The usability of software is greatly increased if there are consistent interface rules. The same function key or command should always execute the same task across different screens. In addition to this, multiple commands should not perform the same function (507). The formats, colours, capitalization, terminology, and abbreviations should all be standardised within the software. This may be controlled through the recording of these items in a design dictionary during the design process (522). Consistency across successive versions of the software and compatibility with paper or non-computer-based systems is also important. Compatibility across different versions of the software may pose a challenge as the desire to introduce new functionality and improved design needs to be considered against consistency (509). Related to consistency is the concept of standardisation. Standardisation refers to applying common user interface features across many different applications and allows a user to learn numerous software applications in a short period of time (509).

7.4.1.6.7 **Simplicity**

To avoid an overload of the cognitive senses, design elements should be used sensibly and sparingly (507) and like-objects should be grouped together (511). The best partition is often the use of blank space between items. Inclusion of multiple colours, blinking characters, and excessive beeps to indicate errors, may distract the user from performing their tasks optimally (507).

7.4.1.6.8 **Tailorability**

Because of the variability in experience and skill of the range of users who are likely to use the same software package, it should be possible to tailor the interface to the specific needs of the present user. The user is able to use time more efficiently if they may select a default starting point, appropriate skill level or preferred output format (507). Flexibility of user control of the interface is also important. It should be possible to alter the display into the most convenient form for the present task (522).

Shortcuts for users who interact with software frequently should be included in the software design. As users become more familiar with software they want to decrease the required number of interactions and hence increase operating speed. The inclusion of abbreviations, special keys and hidden commands all contribute to this end (509).

7.4.1.6.9 **Pointing**

Pointing devices may be used to select either a point or specify a path in one-, two- or three-dimensions (511). Users often find it faster to select an option from the screen with a pointing device such as a mouse. An exception to this may occur in the case where a person is skilled in typing and selection requires a move between touch typing and a pointer (507).

7.4.1.6.10 **Context sensitivity**

The current state of the screen should be reflected in the available options and commands. It requires less effort on the part of the user if options that are inappropriate at the present time are dimmed or made unavailable as then the user does not need to learn and memorise the rules of the software (507).

7.4.1.7 **Report Design**

Reports have a similar format to forms but are normally used for summary purposes. They may be printed, viewed on screen or stored as files to be used by other applications. Screen reports usually result from one-off queries to a database or represent an interim step in an interactive process. Printed reports are utilised in situations where the report is sent to an external establishment, is too large to be read on-line, or is to be used for audit (507). To ensure that a given report fulfils its main purposes there are six principals of good report design namely: relevance, timeliness, accuracy, clarity, readability and cost. A description of each of these principals follows.

7.4.1.7.1 **Relevance**

A rigorous selection process is important when producing a report. Only required information should be included in the report. Information not relevant to the present purpose should be excluded (507).

7.4.1.7.2 **Timeliness**

The majority of reports are used in the process of decision making. Therefore, it is vital firstly that data entry is timely and secondly that reports are produced and delivered to the decision makers before the decision deadline (507).

7.4.1.7.3 **Accuracy**

Accuracy is dependant on the data being correctly entered, transferred and changed into summary data. It should be noted that incomplete data is also considered inaccurate (507).

7.4.1.7.4 **Clarity**

It is important that information included within a report is displayed clearly. Germane information should be easily located and arranged in a logical order. Graphical representations and comparisons should also be incorporated where appropriate (507).

7.4.1.7.5 **Readability**

It has been shown that adult functional literacy levels range between 3 and 5 grades below the highest grade of schooling completed (527). Although the suitability of reading material is affected by a number of factors the primary determinant of comprehension is reading level (528). Gray and Leary (529) computed correlations between comprehension tests and possible elements of difficulty in a group of adults. They found that average sentence length and percentage of one syllable words were of similar use in gauging comprehension difficulty. Flesch used these principals in the development of his reading ease formulae ((530); (531); (532)). The Flesch Reading Ease score is based on a scale of 0 to 100, in which higher scores are easier to read than lower scores (see Table XLVI). The Flesch Kincaid reading level determines the number of years of education generally required to understand a given section of text. It is specified according to the US school grade system (533).

Table XLVI: Interpretation table for Flesch reading ease score (adapted from (534) and (533)).

Flesch Reading Ease Score	Reading Difficulty	Example of Style
91 – 100	Very easy	Reader's Digest
81 – 90	Easy	Time
71 – 80	Fairly Easy	US News & World Report
61 – 70	Standard	New York Times
51 – 60	Fairly difficult	The Ambassadors, by Henry James
31 – 50	Difficult	Corporate annual report
0 – 30	Very Difficult	Legal contract

7.4.1.7.6 **Cost**

There are two main costs associated with each report. The first is the cost of preparation which includes: analysis, design, computation, and circulation. The second cost relates to reading the report and extracting relevant sections. The cost of the later is often mistakenly excluded from the cost calculation. This cost may be reduced through cautious report design and the inclusion of only the information which is directly relevant to the use of the report. In all cases the overall cost must outweigh the benefits, or else the report should not be produced (507).

7.4.1.8 **Conclusions**

Information systems improve the efficiency and effectiveness of mathematically time consuming or mundane tasks by automating them. Planning is vital when starting a new software project to prevent later complications. Entity relationship diagrams, input/output lists and data flow diagrams are instrumental in the planning and analysis phases. During coding and implementation the programmer should pay careful attention to the generally accepted principals of good screen and report design. To create a user friendly interface the programmer should consider: concreteness, visibility, modifiability, interaction, familiar conceptual models, consistency, simplicity, tailorability, pointing, and context sensitivity. To create a suitable system of reports the developer should consider: relevance, timeliness, accuracy, clarity, readability, and cost.

The development of the "Health of the Nation v1.0" software for this thesis followed the methods and guidelines described above. Although there were few stakeholders in the development process, the adherence to widely accepted principals of software planning and good screen and report design ensured the later usability of the software. The final product was able to standardise and streamline the collection, analysis and reporting of the health-related fitness of children according to South African normative data.

7.4.2 **Methodology**

There are currently no normative data available for national health-related fitness characteristics of South African children and hence it is unknown the extent to which low fitness characteristics may be a problem within the South African population. This lack of data can perhaps be attributed in part to the logistical difficulties in gathering information to generate these normative values. Therefore, it is assumed that the automation of testing and data analysis will increase the ability to generate accurate and representative normative data.

This software was created to streamline and standardise the testing and analysis of the physical fitness levels of children between the ages of 6 and 13 years. It also provides for simple reporting methods at both the individual and school level allowing for more efficient feedback. If this application is readily adopted by schools in conjunction with a rewards scheme, it could be instrumental in laying the foundations for renewed interest in physical activity and fitness within South Africa.

Equations for each gender and age grouping were constructed as described in section 3.8.3. These were later used in the programming phase of the software to automate the calculation of age, and gender specific percentile scores for each variable.

The data modelling process was carried out by mapping the relationships between the data entities, through the use of a data-entity diagram. Process modelling was used to create a list of inputs into and outputs from the system. A data flow diagram was used to show the interactions and flow of the data within the system. These methods of analysis have been described in the literature review of this section.

The Health of the Nation software was created to be used in the Microsoft Windows environment. Programming used the Delphi 7.0 programming language (535) and the Rave Report 5.0 developer (536). The database system underlying the software was the Microsoft Access database system (537).

7.4.3 **Results**

To make the research from this dissertation relevant to South Africa as a whole, a software package was developed to facilitate the fitness testing of South African children in the future. This software used the normative data developed in the nutritional status and physical fitness studies to allow users to compare the anthropometric and physical fitness scores of a given child to South African children of similar age and gender.

Table XLVII: Inputs and outputs of the Health of the Nation software system

Inputs	Outputs
Unique code to identify each child	Percentile height of child
Year of testing	Percentile mass of child
Name of child	Percentile BMI of child
School of child	Percentile standing long jump score
Ethnicity of child	Percentile shuttle run score
Socioeconomic code of school	Percentile sit-ups score
Gender of child	Percentile ball throw score
Age of child	Percentile sit-and-reach score
Height of child	
Mass of child	Child report
BMI of child	School report
Comments	
Standing long jump score	
Shuttle run score	
Sit-ups score	
Ball throw score	
Sit-and-reach score	
User name	
Password	

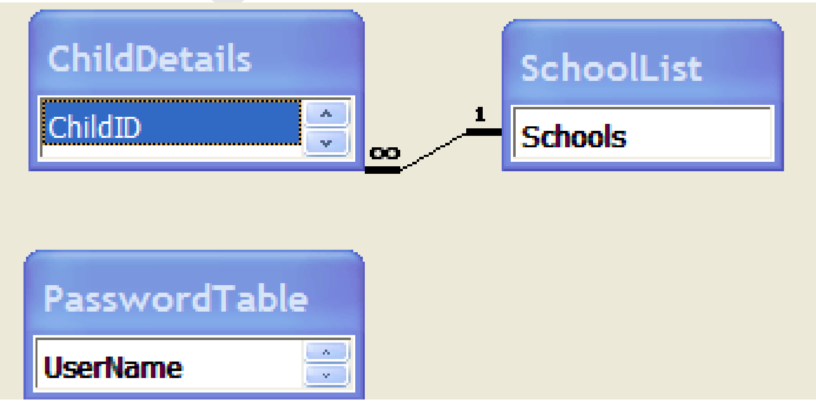


Figure 28: Entity relationship diagram of the Health of the Nation software system

The requirements of the software were assessed through listing the necessary inputs and outputs (Table XLVII). This was the first step in understanding the requirements of the software system. The design of the database tables and the links between each table are illustrated in
Figure 28. This aided in establishing the structure of the database. The structure and flow of the software was planned through the use of the dataflow diagram illustrated in Figure 28.

This software follows the structure of any intelligent database. The user inputs data into the database. These data are processed according to equations programmed into the software. Results are then created which may be filtered and viewed on screen, or printed out as a report. It uses a pull down menu system to navigate between the different functional sections of the program. The suite of tools provided includes: a description of the health-related fitness tests; the ability to add, view and edit the test results for each child; and a section which provides feedback to individuals or schools through reports.

The text used in the reporting system needed to be easily understood by the children. Therefore, a verbal ranking system was used in conjunction with the raw scores of each child to supply all comparative feedback. There was also a need to give an explanation of what each test measured. To ensure that the text used was appropriate for the primary school level, readability tests were conducted. The results of these readability tests revealed that the Flesch Reading Ease Score of the individual child certificates was 76.1% and the Flesch Kincaid reading level was 5.8. The Flesch Reading Ease Score for the school report was 71.3%, while the Flesch Kincaid reading level was grade 5.2.

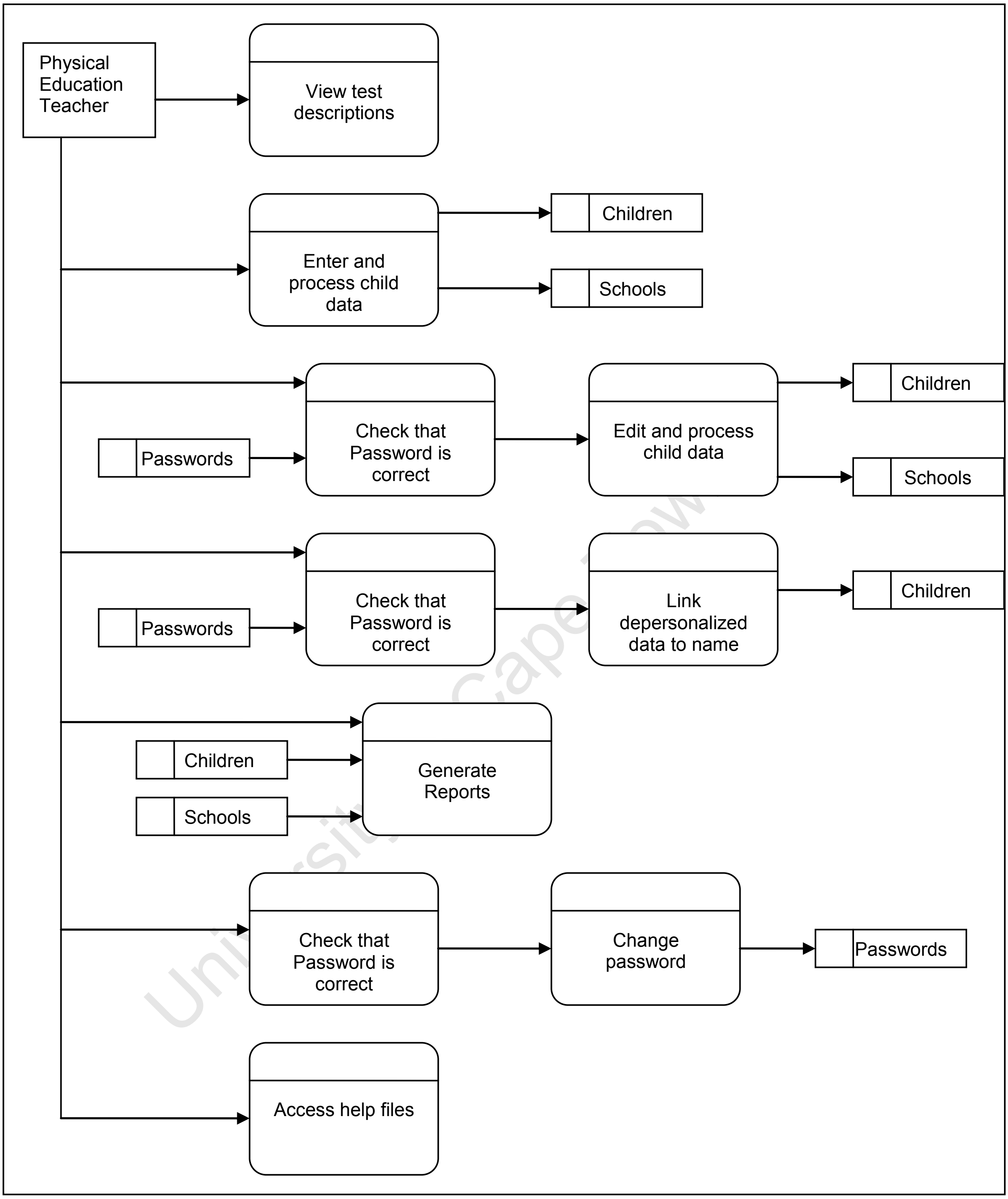


Figure 29: Data flow diagram which provides an overview of the Health of the Nation software system

7.4.4 Discussion and Conclusions

Assessing the physical fitness of children at the national level poses logistical and financial difficulties. Yet, the development of a tool which allows schools to perform a nationally accepted physical fitness test battery and gain automated feedback on their performance would combat some of these challenges. Therefore, the South African normative anthropometric and physical fitness data developed in the first two studies of this dissertation were used to construct a national child fitness testing software package called the Health of the Nation v1.0. A familiar conceptual model, the Microsoft windows environment, allowed for "consistency" and "standardisation" with respect to well known software packages. It was assumed that this would facilitate faster learning of the software by new users.

The Health of the Nation v1.0 software encompasses three main areas, namely: instructions on how tests should be performed, addition and manipulation of records, and presentation of the results. To maintain privacy, a password protection system has been included, which caters for the separation of each child's name from their scores. However, a master user is able to link names with scores when necessary.

To standardise the data collection procedures and ensure accurate comparisons to the national normative data, the software includes a section of test descriptions. For each test, a written description of how to perform the test is provided and a video visually illustrating the test may also be viewed. It is assumed that the use of both a written and a visual description will ensure that users are still able to perform the tests accurately in the absence of a facilitator to demonstrate the tests in person.

The manipulation of records involves both the addition of new children to the database and the editing of the data of children already entered into the database. It is important that this software is easy to use. As such, the principals of good screen design (discussed in section 7.4.1.6, Screen Design) are accommodated wherever possible into the design of the software. For example, during the addition of new records and the editing of existing records, accuracy of the data is maintained by programming the acceptable ranges for each variable into the data entry fields of the software. When unacceptable values are entered, an error message is generated. Integrity of the data is also maintained by only allowing the user to enter the data for one child at a time. This is superior to batch entry systems as errors are not propagated across a number of records before they are detected. “Modifiability”, is facilitated through the inclusion of drop-down menus in a number of the input fields. In these fields the user is able to choose from a number of predefined values or may add a new value if necessary. Although the addition of new records and the editing of previously entered records both use the same software screen, “Context Sensitivity” is maintained by making inappropriate buttons unavailable to the user. “Visibility” is maintained by allowing the user to view context sensitive screen tips which provide information on each data entry field and button when the user places the mouse pointer over the object in question. The principal of “pointing” is ensured by allowing users to choose between the use of a mouse or the “tab” key to navigate between different data entry fields and buttons. “Tailorability” is provided for when viewing records for the children. The user may either choose to view the results of each child separately or they may use the master sheet facility to view the results of a number of different children at the same time.

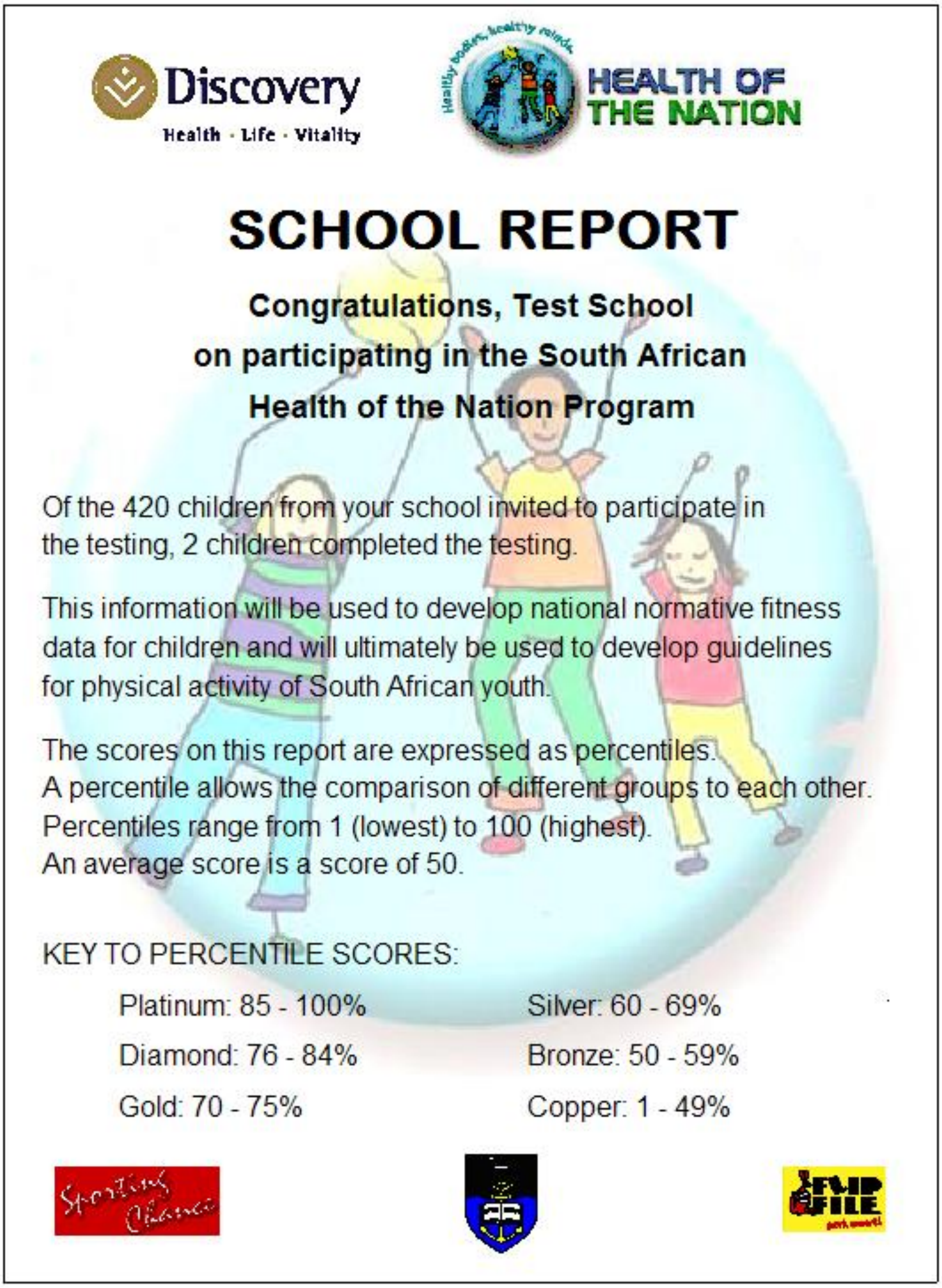
With respect to the reporting system, it is important that the output provided in the reports is clear to teachers, pupils and parents. Additionally, to encourage future participation, the emphasis is on providing positive feedback to each child. Therefore, the only numerical scores given on the child certificates are the actual test results. The score of the child for each test is given a percentile ranking according to the performance of a sample of South African school children of the same gender and age. This numeric percentile ranking is converted to a descriptive ranking according to the ranking system shown in Table XLVIII. “Clarity” and “Readability” of the reports was assessed through the use of a Flesch Reading Ease score. A Flesch Kincaid reading level analysis was used to ensure that the feedback certificates were matched to the reading ability of children in primary school. These analyses showed that the reading level of the certificates is set at a primary school level, although younger children may require the help of teachers or parents when interpreting their results. An example of a physical fitness certificate for a child is seen in Figure 30.

Table XLVIII: Ranking system used when providing feedback on test performance relative to South African normative scores.

PERCENTILE RANGE	RANKING
85 – 100	Platinum
76 – 84	Diamond
70 – 75	Gold
60 – 69	Silver
50 – 59	Bronze
0 – 49	Copper

The School report aims to give basic mean data feedback on each group (gender and age). The data are split into gender and age groups and then the average scores are calculated for each group. The first page of the report explains the purpose of the testing (Figure 31). It also gives an indication of the number of children that participated in the tests in comparison to the number of children who were invited to take part. An explanation of the purpose of the testing follows. A description of percentiles and a key to the descriptive/verbal classifications used in the software is then provided. As with individuals, all comparative data uses a word ranking system (Table XLVIII). The second page of the report explains what is measured by each test included within the test battery (Figure 32). From the third page onwards each page gives feedback on a specific gender and age group (Figure 33). The number of children tested within the specific group is indicated at the top of the page. The actual mean test score is given next to each test name. The mean score is given a percentile ranking according to the performance of a sample of South African school children of the same gender and age and is shown in graphical format at the bottom of the page. The numeric percentile ranking is then converted to a descriptive ranking as with the individual child reports.

Figure 30: Example of a physical fitness certificate for a child provided by the Health of the Nation v1.0 software package.



Discovery
Health · Life · Vitality

HEALTH OF THE NATION

SCHOOL REPORT

Congratulations, Test School on participating in the South African Health of the Nation Program

Of the 420 children from your school invited to participate in the testing, 2 children completed the testing.

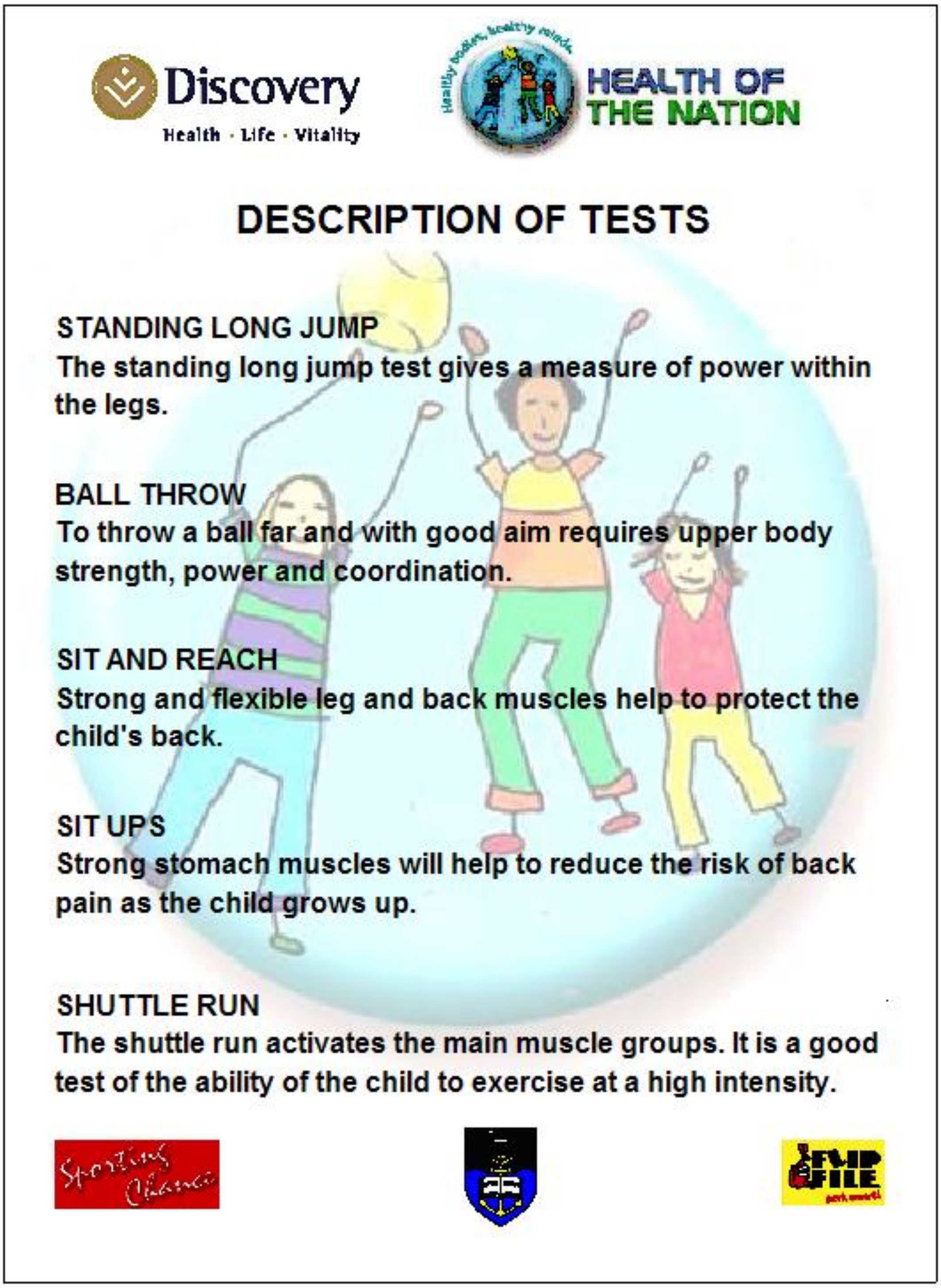
This information will be used to develop national normative fitness data for children and will ultimately be used to develop guidelines for physical activity of South African youth.

The scores on this report are expressed as percentiles.
A percentile allows the comparison of different groups to each other.
Percentiles range from 1 (lowest) to 100 (highest).
An average score is a score of 50.

KEY TO PERCENTILE SCORES:

Platinum: 85 - 100%	Silver: 60 - 69%
Diamond: 76 - 84%	Bronze: 50 - 59%
Gold: 70 - 75%	Copper: 1 - 49%

Figure 31: Example of the first page of the school physical fitness certificate provided by the Health of the Nation v1.0 software package.



DESCRIPTION OF TESTS

STANDING LONG JUMP
The standing long jump test gives a measure of power within the legs.

BALL THROW
To throw a ball far and with good aim requires upper body strength, power and coordination.

SIT AND REACH
Strong and flexible leg and back muscles help to protect the child's back.

SIT UPS
Strong stomach muscles will help to reduce the risk of back pain as the child grows up.

SHUTTLE RUN
The shuttle run activates the main muscle groups. It is a good test of the ability of the child to exercise at a high intensity.

Figure 32: Example of the second page of the school physical fitness certificate provided by the Health of the Nation v1.0 software package.

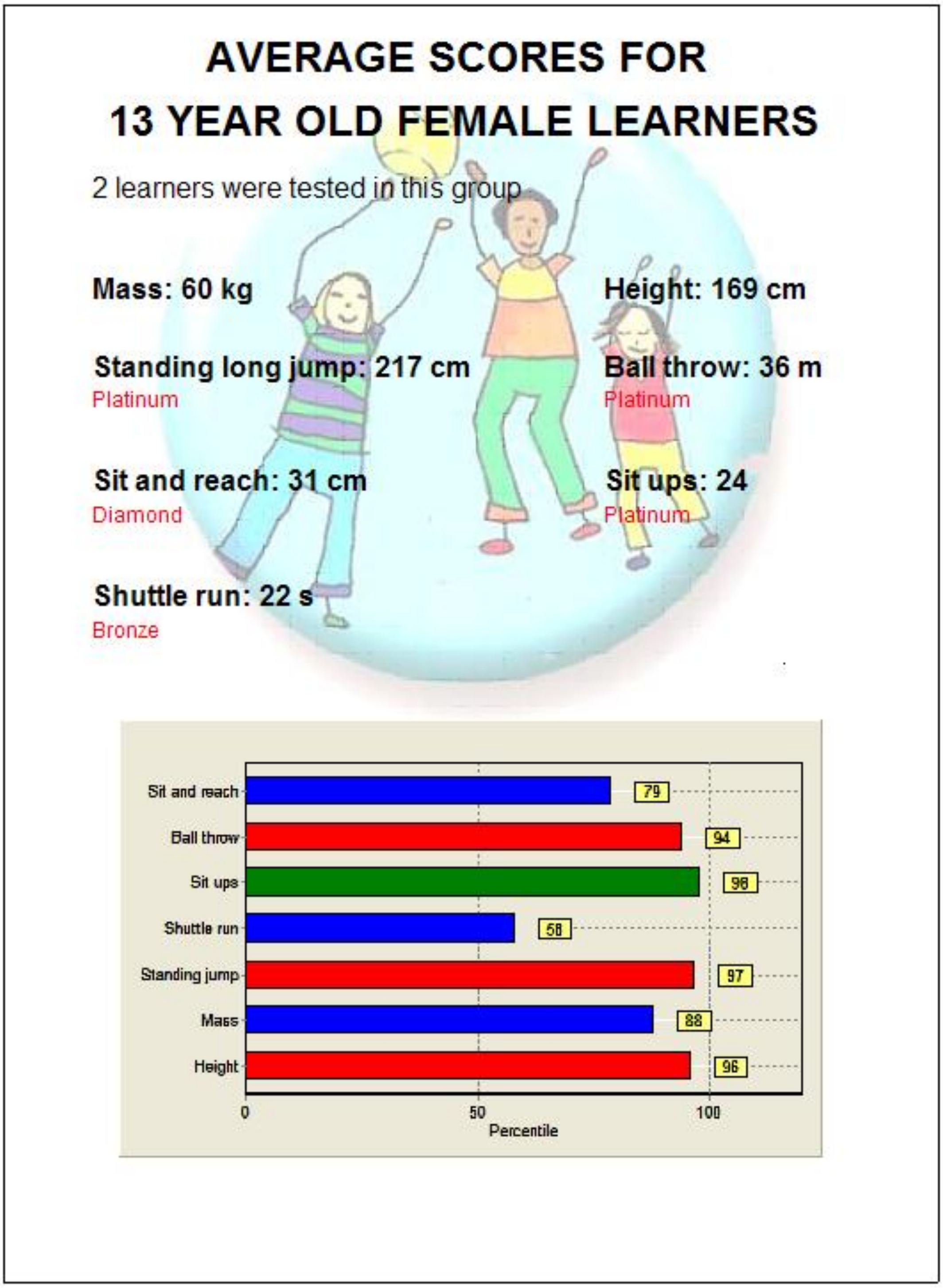


Figure 33: Example of the third page of the school physical fitness certificate provided by the Health of the Nation v1.0 software package.

Four main methods for accessing information on how to use the Health of the Nation Software v1.0 have been included in the software infrastructure. Firstly, hints can be accessed when entering data into fields or when one is unsure of what a given button will do when pressed. To access a hint, the user simply places the mouse arrow over the field or button and the hint appears as a pop-up window. Secondly, a description of most items found in the software appears in the status bar (located at the bottom of the software form), when the mouse arrow is positioned over that item. This option includes information on menu items, data entry fields and buttons. Thirdly, a more detailed description of how to use the Health of the Nation Software v1.0 than that provided by Hints and the Status Bar may be found in the on-line help system of the software. Contents, Index and Find functions add flexibility and allow the user to choose a method to locate help which best suites them. Finally, a user manual which accompanies the software package, gives detailed descriptions of the functionality of the software. All information may be located through the index provided at the back of the user manual.

7.4.5 **Conclusions**

The Health of the Nation Software v1.0 currently allows the results of each child to be compared with the normative data of a representative group of South African children according to age and gender. At present Discovery Vitality are adapting this software into an internet based application. This modification will allow for more widespread use of the software across South Africa as the costs of couriering compact disks to schools will not be necessary. It is hoped that this modification along with a proposed rewards schemes will result in a widespread awareness of the need for physical activity and improved health-related fitness among young South Africans.

7.5 Appendix E: Adaptations to the 5-m shuttle run test

A sample of 309 primary school children not used in the main dataset, including boys and girls of varied ethnicity and ranging in age from 7 to 13 years, completed the Health of the Nation test battery as described in the main methodology section, including the 50 m shuttle run. Following this each child also completed the 100 m shuttle run test protocol once they were fully rested. During the long shuttle run protocol, the time taken to complete the first 10 shuttles was recorded in addition to the time elapsed following the full 20 shuttles. A factorial ANOVA with repeated measures and grouping according to gender and age, was used to identify differences between the three groups, namely: the time taken to complete the short shuttle run, the first 10 shuttles of the long shuttle run, and the final 10 shuttles of the long shuttle run. The Newman-Keuls *post-hoc* test was chosen to identify differences between the three aspects of the shuttle test. This *post-hoc* test is intermediate between the conservative and liberal tests and thereby guards against both type I and type II errors (538). As expected no difference was noted between the time required to finish the short shuttle run and the time required to complete the first 10 shuttles of the long shuttle run. However, in the majority of gender and age groups, there were differences between the time taken to complete the final 10 shuttles in the long shuttle run, and the completion times for the first 10 shuttles of the short and long tests as detailed above. This indicated that a fatigue factor was present in the 100 m test which necessitated a correction for these data to be adjusted to the 50 m equivalent. Therefore, it was proposed that a regression equation should be used to perform the correction between the 100 m and the 50 m shuttle run.

A linear regression between the time taken to complete the 50 m shuttle run and the 100 m shuttle run (Figure 34) gave a correlation coefficient of $r = 0.76$ with a standard error of 0.92 seconds. A third order polynomial regression equation (Figure 35) improved on these values marginally with a correlation coefficient of $r = 0.77$ and a standard error of 0.90 seconds. These correlations did not improve when the dataset were separated according to gender. The predictive ability of these two equations were tested using a linear regression between the actual time taken to complete the 50 m shuttle run, compared to the time predicted from the 100 m shuttle run. Figure 36 and Figure 37 reveal that the non-linear prediction showed a higher correlation coefficient (r = 0.77) and lower standard error (0.69 seconds) than the linear prediction (correlation coefficient = 0.76, standard error = 0.90 seconds).

Bland and Altman (539) warn against the sole use of a regression analysis when deciding whether two measurement techniques agree. The Bland-Altman plot illustrated in Figure 38 showed that more than 95% of the sample lay between the upper and lower limits of agreement. As the initial regression analysis revealed an increasing fatigue factor as the time to complete the test increased, it was assumed that a curvilinear fit; the third order polynomial in this case, would guard again this bias. However, the Bland-Altman plot revealed that the correction model was not fully homoscedastic. Yet, it was deemed that the benefit of the inclusion of the corrected shuttle run data points in the sample outweighed this slight heteroscedacity. Therefore, the Western Cape shuttle run data were corrected using the third order polynomial regression equation illustrated in Figure 35.

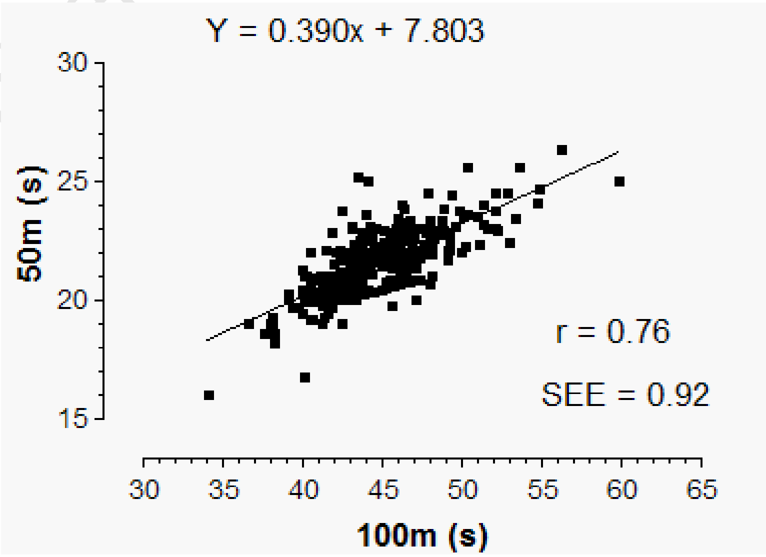


Figure 34: Linear regression equation between the time taken to complete the long and the short shuttle runs.

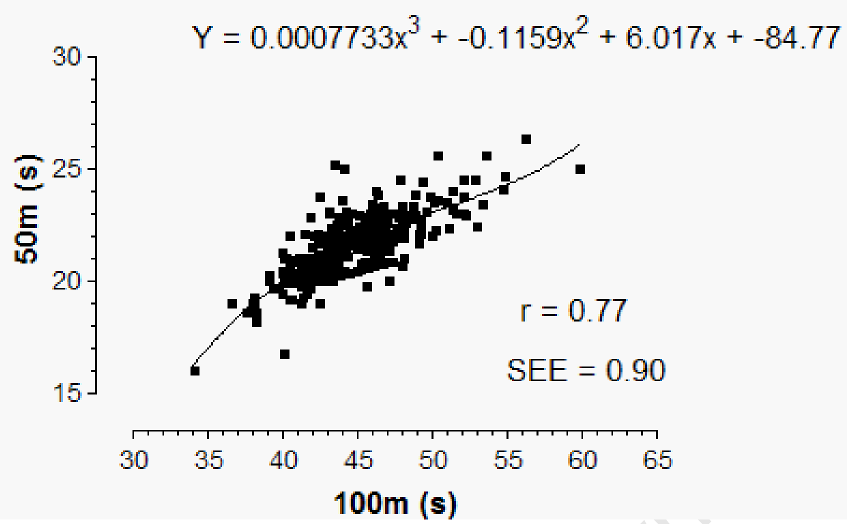


Figure 35: Third order polynomial regression equation between the time taken to complete the long and the short shuttle runs.

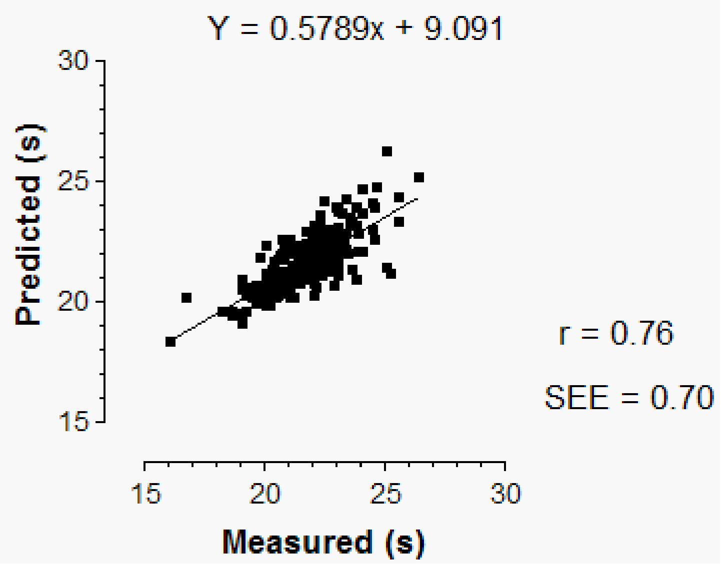


Figure 36: Linear regression between the time taken to complete the short shuttle run and the expected time taken to complete the short shuttle run as predicted using the linear regression from Figure 34.

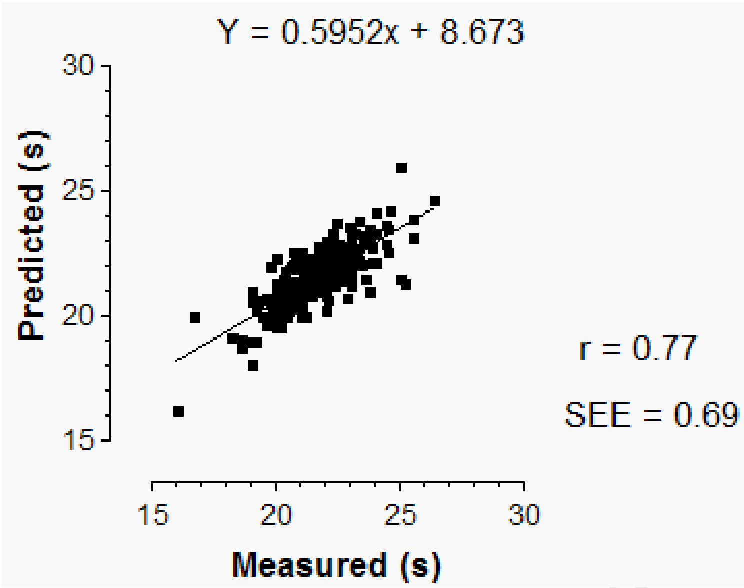


Figure 37: Linear regression between the time taken to complete the short shuttle run and the expected time taken to complete the short shuttle run as predicted using the third order polynomial regression from Figure 35.

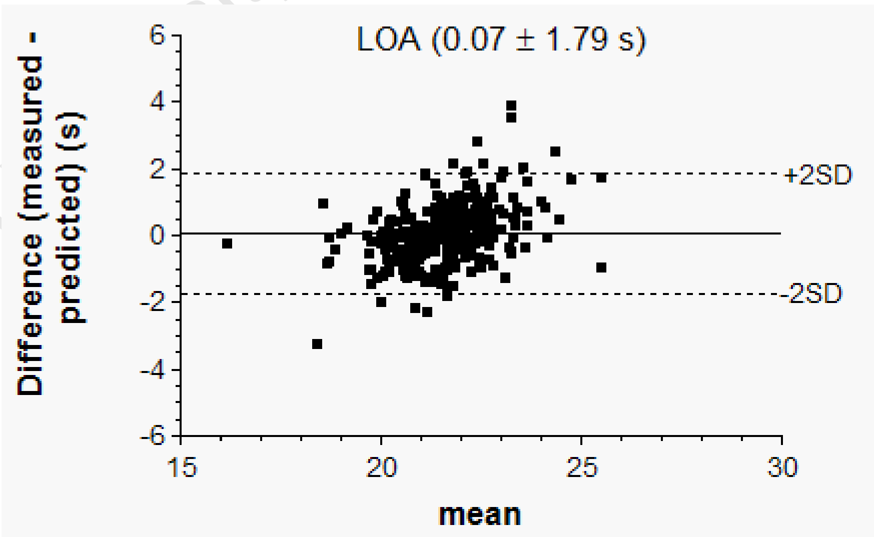


Figure 38: Bland Altman plot illustrating the limits of agreement between the measured and predicted shuttle run scores (LOA = limits of agreement).

7.6 **Appendix F: Interactions Study Tables**

	Sit-and-Reach		Standing Jump		Sit-ups		Shuttle Run		Ball Throw	
	Adjusted	Unadjusted	Adjusted	Unadjusted	Adjusted	Unadjusted	Adjusted	Unadjusted	Adjusted	Unadjusted
Not Overweight/Obese	51.9 ± 28.9 (8409)	51.8 ± 28.8 (8409)	52.6 ± 25.6 (8395)	52.0 ± 28.9 (8395)	52.8 ± 27.4 (8435)	52.4 ± 28.9 (8435)	55.7 ± 25.9 (8401)	55.3 ± 28.2 (8401)	50.7 ± 28.7 (8377)	50.6 ± 28.7 (8377)
Overweight/Obese	49.2 ± 29.1 (1509)	49.7 ± 29.9 (1509)	38.6 ± 25.7 (1508)	41.9 ± 27.8 (1508)	40.4 ± 27.5 (1509)	42.8 ± 29.2 (1509)	45.2 ± 26.1 (1508)	47.8 ± 28.0 (1508)	50.5 ± 28.9 (1500)	50.7 ± 28.9 (1500)
Not mildly stunted	51.3 ± 29.1 (7730)	51.6 ± 29.5 (7730)	51.7 ± 26.1 (7717)	53.3 ± 28.7 (7717)	51.1 ± 28.0 (7747)	52.3 ± 29.0 (7747)	54.4 ± 26.4 (7724)	55.8 ± 27.8 (7724)	51.6 ± 28.9 (7694)	51.7 ± 29.0 (7694)
Mildly stunted	52.1 ± 29.7 (2193)	50.9 ± 27.0 (2193)	46.1 ± 26.7 (2191)	40.3 ± 27.3 (2191)	50.3 ± 28.5 (2202)	46.0 ± 29.3 (2202)	53.1 ± 26.9 (2190)	48.0 ± 29.4 (2190)	47.3 ± 29.4 (2188)	46.9 ± 27.6 (2188)
Not Stunted	51.4 ± 28.9 (9119)	51.6 ± 29.2 (9119)	51.4 ± 25.9 (9104)	52.2 ± 28.7 (9104)	51.3 ± 27.8 (9142)	51.9 ± 29.0 (9142)	54.5 ± 26.2 (9110)	55.2 ± 28.1 (9110)	51.6 ± 28.6 (9082)	51.6 ± 28.7 (9082)
Stunted	51.7 ± 29.6 (804)	50.0 ± 25.7 (804)	40.1 ± 26.5 (804)	31.1 ± 23.9 (804)	46.8 ± 28.4 (807)	40.2 ± 28.4 (807)	50.4 ± 26.8 (804)	42.4 ± 28.7 (804)	40.0 ± 29.3 (800)	39.7 ± 26.6 (800)
Not Wasted	51.5 ± 28.9 (9401)	51.5 ± 28.9 (9401)	50.3 ± 26.0 (9387)	50.3 ± 28.8 (9387)	50.8 ± 27.7 (9426)	50.8 ± 29.1 (9426)	54.0 ± 26.2 (9393)	54.0 ± 28.4 (9393)	51.1 ± 28.6 (9361)	51.1 ± 28.7 (9361)
Wasted	50.5 ± 28.9 (517)	50.5 ± 30.2 (517)	53.6 ± 26.0 (516)	53.4 ± 30.0 (516)	53.0 ± 27.7 (518)	52.9 ± 29.7 (518)	56.2 ± 26.2 (516)	55.8 ± 26.9 (516)	42.9 ± 28.6 (516)	43.0 ± 28.3 (516)
Not Underweight	51.9 ± 28.7 (3615)	52.0 ± 28.6 (3615)	50.8 ± 25.5 (3601)	51.1 ± 28.6 (3601)	51.4 ± 26.9 (3615)	51.6 ± 29.0 (3615)	58.3 ± 26.8 (3589)	58.6 ± 29.1 (3589)	51.8 ± 28.1 (3580)	51.8 ± 28.3 (3580)
Underweight	50.4 ± 28.9 (205)	49.5 ± 29.2 (205)	43.2 ± 25.7 (205)	36.9 ± 29.2 (205)	43.9 ± 27.1 (205)	38.8 ± 27.7 (205)	56.1 ± 27.0 (203)	50.1 ± 30.5 (203)	37.5 ± 28.4 (204)	36.9 ± 26.8 (204)

7.7 Appendix G: Socioeconomic Comparative Tables

Table XLIX: Stature (cm) of black and mixed ancestry boys from high and low socioeconomic status, and white boys from high socioeconomic status (6 to 13 years). Values are expressed as means ± SD and sample size (n).

	Socioeconomic 1		Socioeconomic 5		
Age (yrs)	**Black**	**Mixed ancestry**	**Black**	**Mixed ancestry**	**White**
6	116.6 ± 3.6 (27)	117.0 ± 5.2 (7)	132.0 ± 0.0 (2)	119.3 ± 4.2 (9)	122.8 ± 4.8 (51)
7	119.3 ± 5.1 (52)	122.9 ± 4.8 (19)	124.9 ± 6.7 (10)	122.9 ± 5.8 (18)	125.8 ± 5.6 (134)
8	124.9 ± 6.6 (97)	126.8 ± 7.2 (16)	127.9 ± 5.4 (39)	132.2 ± 4.8 (36)	133.2 ± 6.6 (200)
9	128.7 ± 6.5 (105)	134.1 ± 6.3 (19)	132.3 ± 6.4 (38)	135.8 ± 6.7 (67)	138.0 ± 6.4 (275)
10	134.5 ± 6.7 (115)	134.8 ± 4.3 (16)	138.7 ± 7.4 (63)	140.9 ± 6.1 (97)	143.3 ± 7.2 (300)
11	138.3 ± 7.1 (117)	140.9 ± 9.3 (13)	143.0 ± 7.6 (42)	144.9 ± 7.7 (93)	148.6 ± 6.9 (418)
12	142.2 ± 7.7 (117) [b5]	148.6 ± 9.3 (20)	149.5 ± 7.8 (46) [b1]	151.7 ± 8.2 (70)	154.6 ± 8.2 (468)
13	149.7 ± 8.5 (128) [b5]	148.6 ± 8.2 (17) [m5]	157.1 ± 9.4 (29) [b1]	158.7 ± 9.8 (22) [m1]	160 ± 8.7 (213)
Adjusted Mean	**135.1 (758)**	**135.6 (127)**	**140.2 (269)**	**141.7 (412)**	**145.3 (2059)**

Table L: Stature (cm) of black and mixed ancestry girls from high and low socioeconomic status, and white girls from high socioeconomic status (6 to 13 years). Values are expressed as means ± SD and sample size (n).

	Socioeconomic 1		Socioeconomic 5		
Age (yrs)	**Black**	**Mixed ancestry**	**Black**	**Mixed ancestry**	**White**
6	116.2 ± 4.8 (29)	112.6 ± 4.6 (5)	118.5 ± 3.0 (5)	121.2 ± 4.1 (15)	122.0 ± 5.0 (51)
7	120.1 ± 5.7 (64)	118.7 ± 5.4 (21)	122.4 ± 3.2 (8)	125.9 ± 6.4 (35)	126.5 ± 5.5 (143)
8	124.5 ± 5.4 (114)	129.1 ± 5.7 (17)	129.3 ± 5.3 (17)	131.9 ± 5.3 (30)	131.3 ± 5.8 (199)
9	128.4 ± 6.2 (113)	131.8 ± 6.8 (10)	134.7 ± 8.4 (13)	136.0 ± 7.3 (60)	137.5 ± 6.2 (219)
10	135.0 ± 7.1 (120)	133.4 ± 7.5 (9)	138.8 ± 6.9 (23)	141.4 ± 7.9 (66)	143.4 ± 7.5 (204)
11	141.0 ± 7.5 (144)	142.5 ± 9.9 (14)	147.3 ± 10.2 (15)	147.9 ± 7.0 (79)	149.4 ± 8.0 (174)
12	147.1 ± 7.3 (134)	150.1 ± 7.8 (23)	151.3 ± 8.6 (19)	154.4 ± 7.6 (70)	156.4 ± 6.9 (180)
13	152.8 ± 8.9 (133)	147.7 ± 5.5 (6)	152.9 ± 5.0 (10)	152.9 ± 4.2 (15)	161.0 ± 5.8 (75)
Adjusted Mean	**136.7 (851)**	**134.3 (105)**	**139.3 (110)**	**141.8 (370)**	**141.4 (1245)**

Table LI: Mass (kg) of black and mixed ancestry boys from high and low socioeconomic status, and white boys from high socioeconomic status (6 to 13 years). Values are expressed as means ± SD and sample size (n).

	Socioeconomic 1		Socioeconomic 5		
Age (yrs)	Black	Mixed ancestry	Black	Mixed ancestry	White
6	20.8 ± 2.1 (28)	19.6 ± 2.6 (7)	28.5 ± 0.7 (2)	21.3 ± 3.2 (9)	25.1 ± 5.3 (51)
7	22.3 ± 2.5 (52)	24.4 ± 4.1 (19)	27.2 ± 5.8 (10)	23.0 ± 4.0 (18)	26.2 ± 4.4 (134)
8	25.1 ± 3.9 (97)	24.4 ± 4.0 (16)	27.9 ± 6.7 (39)	28.2 ± 4.8 (36)	30.1 ± 5.4 (200)
9	26.5 ± 4.1 (105)	28.9 ± 5.8 (19)	30.2 ± 7.1 (38)	31.1 ± 8.7 (67)	32.4 ± 7.1 (274)
10	30.2 ± 5.5 (115) [b5]	29.7 ± 4.8 (16)	35.6 ± 10.1 (63) [b1]	34.9 ± 9.6 (97)	36.9 ± 9.1 (301)
11	31.0 ± 4.9 (117) [b5]	35.5 ± 11.4 (13)	39.6 ± 10.8 (42) [b1]	37.8 ± 9.4 (93)	40.8 ± 9.1 (417)
12	35.6 ± 6.7 (117) [b5]	37.3 ± 8.5 (20)	43.0 ± 10.6 (46) [b1]	41.7 ± 8.7 (70)	44.7 ± 10.4 (468)
13	39.9 ± 8.9 (128) [b5]	35.7 ± 5.9 (17) [m5]	49.8 ± 11.8 (29) [b1]	47.2 ± 12.2 (22) [m1]	50.7 ± 11.7 (213)
Adjusted Mean	**30.7 (759)**	**30.2 (127)**	**36.8 (269)**	**35.3 (412)**	**38.6 (2058)**

Table LII: Mass (kg) of black and mixed ancestry girls from high and low socioeconomic status, and white girls from high socioeconomic status (6 to 13 years). Values are expressed as means ± SD and sample size (n).

	Socioeconomic 1		Socioeconomic 5		
Age (yrs)	Black	Mixed ancestry	Black	Mixed ancestry	White
6	20.5 ± 2.9 (29)	19.2 ± 4.6 (5)	22.7 ± 4.0 (5)	20.7 ± 5.8 (15)	23.8 ± 4.4 (51)
7	23.2 ± 4.0 (64)	21.3 ± 4.0 (22)	23.7 ± 3.3 (8)	26.2 ± 9.0 (35)	26.2 ± 5.3 (143)
8	24.8 ± 4.0 (114)	28.8 ± 7.6 (17)	30.1 ± 6.0 (17)	26.4 ± 5.0 (30)	28.6 ± 6.0 (199)
9	27.1 ± 5.4 (113)	27.8 ± 4.3 (10)	32.5 ± 7.3 (13)	31.0 ± 7.6 (60)	32.3 ± 6.6 (219)
10	31.5 ± 7.3 (121)	33.0 ± 8.3 (9)	35.8 ± 7.3 (23)	34.8 ± 10.1 (66)	37.4 ± 9.3 (204)
11	35.5 ± 8.1 (144)	38.4 ± 8.0 (14)	41.5 ± 12.3 (15)	40.7 ± 11.5 (79)	41.8 ± 10.0 (174)
12	41.3 ± 8.8 (134)	41.7 ± 8.1 (23)	46.1 ± 9.1 (19)	45.5 ± 10.9 (70)	46.9 ± 11.4 (180)
13	46.5 ± 8.7 (133)	36.2 ± 5.5 (6)	54.4 ± 10.8 (10)	43.6 ± 4.5 (15)	50.4 ± 8.4 (75)
Adjusted Mean	**33.6 (852)**	**31.5 (106)**	**37.3 (110)**	**35.8 (370)**	**36.0 (1245)**

Table LIII: BMI of black and mixed ancestry boys from high and low socioeconomic status, and white boys from high socioeconomic status (6 to 13 years). Values are expressed as means ± SD and sample size (n).

	Socioeconomic 1		Socioeconomic 5		
Age (yrs)	**Black**	**Mixed ancestry**	**Black**	**Mixed ancestry**	**White**
6	15.4 ± 1.0 (27)	14.3 ± 1.2 (7)	16.4 ± 0.4 (2)	14.9 ± 1.6 (9)	16.5 ± 2.5 (51)
7	15.7 ± 1.6 (52)	16.3 ± 2.1 (18)	17.3 ± 2.3 (10)	15.1 ± 2.1 (18)	16.5 ± 1.9 (134)
8	16.0 ± 1.8 (97)	15.1 ± 1.6 (16)	16.9 ± 3.3 (39)	16.1 ± 2.1 (36)	16.9 ± 2.2 (200)
9	16.0 ± 1.6 (105)	15.9 ± 2.0 (19)	17.3 ± 4.0 (38)	16.7 ± 3.4 (67)	16.9 ± 2.7 (274)
10	16.6 ± 2.4 (115) [b5]	16.3 ± 2.3 (16)	18.3 ± 3.9 (63) [b1]	17.4 ± 3.7 (97)	17.8 ± 3.2 (300)
11	16.2 ± 1.9 (117) [b5]	17.8 ± 5.2 (13)	19.2 ± 4.0 (42) [b1]	17.9 ± 3.6 (93)	18.3 ± 3.2 (417)
12	17.6 ± 2.9 (117)	16.7 ± 2.2 (20)	19.1 ± 3.5 (46)	18.0 ± 2.9 (70)	18.6 ± 3.2 (468)
13	17.7 ± 2.8 (128)	16.1 ± 1.7 (17)	20.0 ± 3.4 (29)	18.6 ± 3.8 (22)	19.6 ± 3.3 (213)
Adjusted Mean	**16.6 (758)**	**16.2 (126)**	**18.4 (269)**	**17.3 (412)**	**17.9 (2057)**

Table LIV: BMI of black and mixed ancestry girls from high and low socioeconomic status, and white girls from high socioeconomic status (6 to 13 years). Values are expressed as means ± SD and sample size (n).

	Socioeconomic 1		Socioeconomic 5		
Age (yrs)	**Black**	**Mixed ancestry**	**Black**	**Mixed ancestry**	**White**
6	15.2 ± 1.7 (29)	15.0 ± 2.3 (5)	16.1 ± 2.4 (5)	14.0 ± 3.5 (15)	15.9 ± 2.2 (51)
7	16.1 ± 2.2 (64)	15.1 ± 2.3 (21)	15.8 ± 1.7 (8)	16.3 ± 4.4 (35)	16.3 ± 2.7 (143)
8	15.9 ± 2.1 (114)	17.2 ± 3.4 (17)	18.0 ± 3.3 (17)	15.1 ± 2.3 (30)	16.5 ± 2.8 (199)
9	16.3 ± 2.3 (113)	15.9 ± 1.7 (10)	17.9 ± 3.2 (13)	16.6 ± 3.1 (60)	17.0 ± 2.8 (219)
10	17.2 ± 3.0 (120)	18.4 ± 4.0 (9)	18.5 ± 3.2 (23)	17.2 ± 3.4 (66)	18.0 ± 3.4 (204)
11	17.8 ± 3.3 (144)	19.2 ± 5.4 (14)	18.9 ± 4.5 (15)	18.5 ± 4.4 (79)	18.6 ± 3.5 (174)
12	19.0 ± 3.4 (134)	18.4 ± 2.9 (23)	20.0 ± 2.8 (19)	19.0 ± 4.1 (70)	19.1 ± 3.9 (180)
13	19.9 ± 3.8 (133)	16.5 ± 1.5 (6)	23.3 ± 4.5 (10)	18.6 ± 1.7 (15)	19.4 ± 2.8 (75)
Adjusted Mean	**17.6 (851)**	**17.1 (105)**	**18.8 (110)**	**17.4 (370)**	**17.6 (1245)**

Table LV: Sit-and-reach scores (cm) of black and mixed ancestry boys from high and low socioeconomic status, and white boys from high socioeconomic status (6 to 13 years). Values are expressed as means ± SD and sample size (n).

	Socioeconomic 1		Socioeconomic 5		
Age (yrs)	**Black**	**Mixed ancestry**	**Black**	**Mixed ancestry**	**White**
6	24.1 ± 6.9 (28)	17.0 ± 3.7 (7)	18.0 ± 1.4 (2)	23.8 ± 6.4 (9)	18.8 ± 7.3 (49)
7	20.8 ± 6.4 (52)	20.4 ± 4.6 (20)	18.7 ± 8.2 (10)	16.0 ± 6.3 (17)	19.9 ± 7.6 (133)
8	23.0 ± 6.3 (96)	19.3 ± 6.3 (16)	21.3 ± 6.8 (39)	19.7 ± 10.0 (36)	21.2 ± 7.6 (200)
9	22.6 ± 5.0 (105)	19.3 ± 4.1 (19)	20.3 ± 7.0 (38)	22.3 ± 8.1 (67)	20.8 ± 8.4 (275)
10	21.8 ± 5.3 (115)	20.6 ± 5.2 (16)	21.4 ± 7.6 (63)	22.9 ± 8.4 (96)	21.4 ± 8.0 (298)
11	20.1 ± 5.2 (117)	17.5 ± 5.0 (13)	22.7 ± 6.1 (41)	22.6 ± 9.2 (91)	22.9 ± 10.6 (412)
12	19.4 ± 5.2 (117)	15.8 ± 4.7 (20)	19.9 ± 6.8 (46)	22.2 ± 8.1 (69)	21.1 ± 8.3 (463)
13	21.4 ± 6.7 (128)	20.4 ± 4.3 (17)	21.9 ± 8.7 (29)	20.4 ± 9.4 (22)	19.8 ± 8.8 (206)
Adjusted Mean	**21.4 (755)**	**18.9 (128)**	**21.1 (268)**	**21.9 (407)**	**21.2 (2036)**

Table LVI: Sit-and-reach scores (cm) of black and mixed ancestry girls from high and low socioeconomic status, and white girls from high socioeconomic status (6 to 13 years). Values are expressed as means ± SD and sample size (n).

	Socioeconomic 1		Socioeconomic 5		
Age (yrs)	**Black**	**Mixed ancestry**	**Black**	**Mixed ancestry**	**White**
6	24.3 ± 6.7 (29)	13.2 ± 5.0 (5)	25.7 ± 8.1 (5)	17.0 ± 10.4 (15)	25.7 ± 7.2 (51)
7	24.5 ± 5.2 (64) [m1]	18.1 ± 5.0 (22) [b1]	23.6 ± 7.4 (8)	20.2 ± 11.0 (35)	25.7 ± 8.0 (143)
8	24.0 ± 5.6 (114)	21.7 ± 6.1 (17)	26.0 ± 7.7 (17)	25.8 ± 8.3 (30)	27.8 ± 6.7 (198)
9	24.0 ± 4.9 (113)	23.2 ± 4.7 (10)	22.9 ± 7.7 (13)	25.2 ± 7.2 (60)	26.4 ± 7.4 (219)
10	23.5 ± 5.4 (117)	24.4 ± 4.4 (9)	27.9 ± 7.4 (23)	26.5 ± 7.0 (66)	24.7 ± 8.0 (204)
11	22.6 ± 5.7 (143)	22.2 ± 5.5 (14)	28.0 ± 7.6 (15)	25.2 ± 8.5 (78)	26.1 ± 7.7 (174)
12	24.1 ± 6.2 (134)	24.3 ± 6.6 (23)	26.7 ± 7.1 (19)	25.0 ± 10.1 (70)	25.4 ± 10.0 (180)
13	27.1 ± 7.1 (133)	26.0 ± 7.8 (6)	23.7 ± 10.6 (10)	24.6 ± 12.0 (15)	27.2 ± 8.6 (75)
Adjusted Mean	**24.2 (847)**	**21.8 (106)**	**26.0 (110)**	**24.6 (369)**	**26.1 (1244)**

Table LVII: Standing long jump scores (cm) of black and mixed ancestry boys from high and low socioeconomic status, and white boys from high socioeconomic status (6 to 13 years). Values are expressed as means ± SD and sample size (n).

	Socioeconomic 1		Socioeconomic 5		
Age (yrs)	**Black**	**Mixed ancestry**	**Black**	**Mixed ancestry**	**White**
6	118.7 ± 18.3 (28)	99.3 ± 33.6 (7)	137.5 ± 14.8 (2)	125.7 ± 17.9 (9)	128.6 ± 19.8 (51)
7	121.4 ± 15.7 (51)	119.9 ± 20.6 (20)	130.8 ± 9.3 (9)	144.3 ± 14.9 (18)	143.4 ± 18.0 (134)
8	130.5 ± 18.3 (95)	140.8 ± 15.8 (16)	142.8 ± 17.6 (39)	154.7 ± 18.9 (36)	160.0 ± 18.1 (200)
9	141.7 ± 24.8 (105)	149.2 ± 17.9 (19)	147.7 ± 24.6 (38)$^{w5\ m5}$	169.6 ± 22.5 (67) ^{b5}	167.9 ± 19.0 (275) ^{b5}
10	152.1 ± 21.8 (112) ^{b5}	158.7 ± 21.8 (16)	166.9 ± 22.9 (62) ^{b1}	177.1 ± 18.6 (96)	174.0 ± 21.1 (300)
11	154.4 ± 17.8 (117) ^{b5}	150.7 ± 26.1 (13) ^{m5}	171.0 ± 20.9 (42) ^{b1}	184.0 ± 21.6 (93) ^{m1}	182.8 ± 22.4 (419)
12	160.6 ± 19.1 (117) ^{b5}	181.4 ± 21.6 (20)	180.2 ± 20.7 (46)$^{b1\ m5}$	197.1 ± 25.3 (70) ^{b5}	189.1 ± 21.4 (467)
13	167.9 ± 20.4 (122) ^{b5}	186.8 ± 23.4 (17)	195.2 ± 24.2 (29) ^{b1}	202.7 ± 23.1 (22)	197.4 ± 22.9 (210)
Adjusted Mean	**148.8 (747)**	**152.2 (128)**	**165.2 (267)**	**177.7 (411)**	**176.3 (2056)**

Table LVIII: Standing long jump scores (cm) of black and mixed ancestry girls from high and low socioeconomic status, and white girls from high socioeconomic status (6 to 13 years). Values are expressed as means ± SD and sample size (n).

	Socioeconomic 1		Socioeconomic 5		
Age (yrs)	**Black**	**Mixed ancestry**	**Black**	**Mixed ancestry**	**White**
6	101.3 ± 15.7 (29)	86.0 ± 15.2 (5)	94.6 ± 15.0 (5)	116.9 ± 16.1 (15)	128.0 ± 17.1 (51)
7	114.2 ± 15.9 (64)	111.2 ± 17.8 (22)	122.0 ± 19.5 (8)	121.8 ± 23.7 (34)	134.9 ± 17.7 (142)
8	125.5 ± 20.9 (111)	134.4 ± 31.6 (17)	135.7 ± 20.1 (17)	151.0 ± 19.2 (30)	149.0 ± 21.8 (199)
9	134.8 ± 19.7 (113)	142.6 ± 14.9 (10)	138.8 ± 27.5 (13)	152.1 ± 23.3 (60)	155.7 ± 19.9 (219)
10	139.8 ± 19.6 (116)	151.3 ± 18.9 (9)	155.7 ± 23.8 (23)	167.2 ± 20.8 (66)	162.0 ± 20.5 (204)
11	149.4 ± 21.0 (143)	166.5 ± 23.6 (14)	162.6 ± 19.6 (15)	168.3 ± 21.2 (79)	171.9 ± 19.3 (174)
12	151.7 ± 24.1 (134)	166.1 ± 21.6 (23)	172.0 ± 20.0 (19)	178.7 ± 26.7 (70)	178.8 ± 22.8 (177)
13	160.4 ± 25.3 (130)	177.7 ± 20.6 (6)	166.5 ± 16.9 (10)	184.7 ± 25.9 (15)	186.2 ± 23.9 (75)
Adjusted Mean	**140.7 (840)**	**143.1 (106)**	**150.1 (110)**	**160.3 (369)**	**159.6 (1241)**

Table LIX: Sit-up scores of black and mixed ancestry boys from high and low socioeconomic status, and white boys from high socioeconomic status (6 to 13 years). Values are expressed as means ± SD and sample size (n).

	Socioeconomic 1		Socioeconomic 5		
Age (yrs)	**Black**	**Mixed ancestry**	**Black**	**Mixed ancestry**	**White**
6	9.3 ± 4.9 (28)	7.4 ± 8.3 (7)	12.5 ± 3.5 (2)	13.6 ± 3.6 (9)	14.0 ± 5.7 (51)
7	10.2 ± 5.0 (52)	10.6 ± 4.9 (20)	13.9 ± 4.0 (10)	15.9 ± 3.5 (18)	15.2 ± 4.8 (133)
8	12.3 ± 4.5 (93) [b5]	15.4 ± 5.4 (16)	17.1 ± 5.9 (39) [b1]	17.5 ± 6.3 (36)	18.1 ± 4.1 (200)
9	14.4 ± 5.1 (105)	16.1 ± 3.7 (19)	17.3 ± 6.5 (38)	19.2 ± 5.2 (67)	18.7 ± 5.1 (275)
10	15.8 ± 5.4 (115) [b5]	18.4 ± 4.8 (16)	19.5 ± 4.8 (62) [b1]	19.6 ± 4.9 (97)	19.8 ± 4.4 (302)
11	17.0 ± 4.6 (117)	16.7 ± 4.0 (13)	18.6 ± 6.0 (42)	20.5 ± 4.6 (92)	20.9 ± 4.4 (417)
12	18.6 ± 4.4 (117)	19.2 ± 3.9 (20)	20.5 ± 5.5 (46)	21.4 ± 4.8 (70)	21.7 ± 4.2 (468)
13	18.6 ± 4.7 (128)	19.5 ± 5.1 (17)	22.1 ± 4.6 (29)	21.9 ± 3.4 (22)	21.7 ± 4.7 (211)
Adjusted Mean	**15.6 (755)**	**16.0 (128)**	**18.9 (268)**	**19.7 (411)**	**19.9 (2057)**

Table LX: Sit-up scores of black and mixed ancestry girls from high and low socioeconomic status, and white girls from high socioeconomic status (6 to 13 years). Values are expressed as means ± SD and sample size (n).

	Socioeconomic 1		Socioeconomic 5		
Age (yrs)	**Black**	**Mixed ancestry**	**Black**	**Mixed ancestry**	**White**
6	4.4 ± 4.5 (29)	4.0 ± 3.7 (5)	7.2 ± 3.4 (5)	10.1 ± 2.3 (15)	10.2 ± 4.3 (51)
7	6.8 ± 5.4 (64)	8.0 ± 4.4 (22)	6.9 ± 5.1 (8)	10.6 ± 5.9 (35)	12.4 ± 4.4 (143)
8	9.9 ± 5.2 (114)	10.4 ± 7.3 (17)	10.8 ± 5.9 (17)	15.4 ± 5.1 (30)	13.9 ± 4.7 (199)
9	10.4 ± 4.3 (113)	13.6 ± 5.3 (10)	11.7 ± 4.9 (13)	16.0 ± 6.0 (60)	16.2 ± 4.9 (219)
10	12.9 ± 4.6 (121)	14.8 ± 4.8 (9)	14.1 ± 5.3 (23)	17.2 ± 5.8 (66)	16.0 ± 4.7 (203)
11	13.0 ± 5.7 (144)	17.9 ± 4.7 (14)	13.9 ± 3.3 (15)	16.1 ± 5.1 (79)	17.3 ± 3.8 (174)
12	13.0 ± 5.8 (134)	14.7 ± 6.0 (23)	15.5 ± 4.9 (19)	16.2 ± 5.2 (70)	17.2 ± 4.7 (179)
13	14.6 ± 4.7 (133)	18.3 ± 4.5 (6)	16.0 ± 3.7 (10)	16.7 ± 2.7 (15)	17.8 ± 3.5 (74)
Adjusted Mean	**11.7 (852)**	**12.6 (106)**	**12.9 (110)**	**15.5 (370)**	**15.5 (1242)**

Table LXI: Shuttle run scores (s) of black and mixed ancestry boys from high and low socioeconomic status, and white boys from high socioeconomic status (6 to 13 years). Values are expressed as means ± SD and sample size (n).

	Socioeconomic 1		Socioeconomic 5		
Age (yrs)	**Black**	**Mixed ancestry**	**Black**	**Mixed ancestry**	**White**
6	25.4 ± 2.6 (27)	27.3 ± 2.3 (7) [m5]	25.0 ± 0.0 (2)	23.9 ± 1.4 (9) [m1]	23.9 ± 2.0 (51)
7	25.5 ± 2.0 (52)	24.3 ± 2.6 (20)	24.7 ± 1.7 (10)	22.9 ± 1.6 (18)	23.2 ± 2.1 (133)
8	24.9 ± 2.2 (91) [m1]	21.7 ± 2.2 (16) [b1]	23.6 ± 2.6 (39) [w5]	22.3 ± 1.3 (35)	22.1 ± 1.4 (199) [b5]
9	23.4 ± 2.1 (103)	21.3 ± 2.0 (19)	22.8 ± 1.6 (38)	21.9 ± 1.4 (66)	21.9 ± 1.4 (275)
10	23.2 ± 1.9 (114)	20.5 ± 2.9 (16)	22.0 ± 1.6 (62)	21.5 ± 1.1 (97)	21.3 ± 1.3 (301)
11	23.3 ± 3.1 (117) [b5]	20.5 ± 1.7 (13)	21.7 ± 2.5 (42) [b1]	21.4 ± 1.2 (93)	20.9 ± 1.3 (419)
12	22.3 ± 2.3 (117) [m1]	19.3 ± 1.2 (20) [b1 m5]	21.0 ± 1.4 (46)	21.0 ± 1.5 (70) [m1]	20.7 ± 1.3 (468)
13	22.3 ± 1.6 (128) [m1]	18.6 ± 1.6 (17) [b1 m5]	20.5 ± 1.3 (29)	21.0 ± 1.1 (22) [m1]	20.9 ± 1.8 (212)
Adjusted Mean	**23.4 (749)**	**21.3 (128)**	**22.1 (268)**	**21.6 (410)**	**21.4 (2058)**

Table LXII: Shuttle run scores (s) of black and mixed ancestry girls from high and low socioeconomic status, and white girls from high socioeconomic status (6 to 13 years). Values are expressed as means ± SD and sample size (n).

	Socioeconomic 1		Socioeconomic 5		
Age (yrs)	**Black**	**Mixed ancestry**	**Black**	**Mixed ancestry**	**White**
6	26.0 ± 2.8 (28)	27.8 ± 3.4 (5) [m5]	25.8 ± 2.5 (5)	24.2 ± 1.5 (15) [m1]	24.5 ± 2.0 (51)
7	26.0 ± 2.7 (63)	24.8 ± 3.2 (22)	26.5 ± 3.2 (8) [w5]	24.0 ± 2.0 (35)	23.7 ± 1.5 (142) [b5]
8	24.5 ± 1.9 (112)	22.7 ± 2.1 (17)	24.0 ± 2.0 (17)	22.3 ± 0.7 (30)	23.1 ± 1.4 (198)
9	24.1 ± 2.4 (112)	22.5 ± 1.5 (10)	25.0 ± 2.8 (13) [m5 w5]	22.4 ± 1.4 (60) [b5]	22.5 ± 1.4 (218) [b5]
10	23.9 ± 2.2 (121)	21.9 ± 1.8 (9)	23.0 ± 1.9 (23)	22.0 ± 1.0 (66)	21.9 ± 1.3 (204)
11	23.6 ± 2.4 (144) [m1]	20.1 ± 1.6 (14) [b1]	22.5 ± 1.7 (15)	22.0 ± 1.0 (78)	21.6 ± 1.2 (174)
12	23.7 ± 2.5 (134) [m1]	20.6 ± 2.1 (23) [b1]	22.0 ± 1.9 (19)	22.1 ± 0.9 (70)	21.4 ± 1.2 (178)
13	23.2 ± 2.2 (133)	19.5 ± 1.6(6)	22.9 ± 1.8 (10)	21.7 ± 0.7 (15)	21.2 ± 1.1 (75)
Adjusted Mean	**24.0 (847)**	**22.3 (106)**	**23.5 (110)**	**22.4 (369)**	**22.4 (1240)**

Table LXIII: Cricket ball throw scores (m) of black and mixed ancestry boys from high and low socioeconomic status, and white boys from high socioeconomic status (6 to 13 years). Values are expressed as means ± SD and sample size (n).

	Socioeconomic 1		Socioeconomic 5		
Age (yrs)	**Black**	**Mixed ancestry**	**Black**	**Mixed ancestry**	**White**
6	12.2 ± 3.7 (28)	11.9 ± 4.5 (7)	20.0 ± 1.4 (2)	13.2 ± 4.0 (9)	12.8 ± 4.8 (51)
7	13.7 ± 4.0 (52)	17.7 ± 4.3 (20)	13.0 ± 2.5 (10)	17.3 ± 6.7 (18)	16.4 ± 5.9 (134)
8	16.5 ± 4.7 (88)	19.9 ± 5.8 (16)	16.7 ± 5.0 (39)	20.5 ± 7.2 (36)	21.0 ± 6.5 (191)
9	20.4 ± 6.5 (104)	22.3 ± 5.5 (19)	18.6 ± 6.4 (36)	23.5 ± 7.9 (64)	23.6 ± 6.8 (263)
10	23.8 ± 7.1 (111)	28.0 ± 3.9 (16)	25.6 ± 6.6 (63)	27.0 ± 7.3 (97)	27.8 ± 7.6 (302)
11	25.3 ± 6.3 (113)	27.5 ± 7.1 (13)	27.6 ± 6.5 (42)	27.7 ± 8.6 (93)	31.4 ± 8.6 (419)
12	28.3 ± 6.5 (115)	32.0 ± 8.4 (18)	31.5 ± 7.1 (46)	34.6 ± 7.8 (70)	36.2 ± 8.7 (468)
13	30.7 ± 7.3 (124)[b5]	37.1 ± 7.0 (15)	37.8 ± 9.0 (29) [b1]	36.9 ± 13.1 (22)	39.2 ± 10.0 (213)
Adjusted Mean	**23.4 (735)**	**25.1 (124)**	**25.5 (267)**	**27.1 (409)**	**29.4 (2041)**

Table LXIV: Cricket ball throw scores (m) of black and mixed ancestry girls from high and low socioeconomic status, and white girls from high socioeconomic status (6 to 13 years). Values are expressed as means ± SD and sample size (n).

	Socioeconomic 1		Socioeconomic 5		
Age (yrs)	**Black**	**Mixed ancestry**	**Black**	**Mixed ancestry**	**White**
6	8.5 ± 2.9 (29)	8.0 ± 4.1 (5)	6.6 ± 2.4 (5)	7.7 ± 2.8 (15)	7.2 ± 2.2 (50)
7	10.9 ± 3.6 (64)	8.5 ± 2.5 (22)	8.6 ± 3.7 (8)	8.4 ± 2.9 (35)	8.6 ± 2.8 (143)
8	13.0 ± 3.3 (113)	13.5 ± 4.8 (17)	11.6 ± 3.2 (16)	11.6 ± 4.7 (30)	10.1 ± 3.2 (199)
9	14.7 ± 4.4 (113)	13.0 ± 4.1 (10)	13.2 ± 3.9 (13)	13.3 ± 3.8 (60)	12.7 ± 4.4 (219)
10	18.0 ± 4.9 (116)	12.9 ± 4.0 (9)	17.2 ± 5.7 (23)	16.0 ± 4.8 (66)	13.6 ± 3.7 (204)
11	21.6 ± 4.9 (137)	21.2 ± 3.9 (14)	17.2 ± 4.8 (15)	16.4 ± 5.3 (79)	16.3 ± 5.2 (174)
12	23.2 ± 5.2 (134)	22.5 ± 5.7 (19)	23.6 ± 5.4 (19) [m5]	17.3 ± 5.7 (69) [b5]	19.2 ± 6.6 (179)
13	25.2 ± 6.9 (133)	19.2 ± 5.7 (6)	21.0 ± 4.4 (10)	24.6 ± 7.1 (15)	19.4 ± 7.2 (75)
Adjusted Mean	**18.6 (839)**	**15.1 (102)**	**16.2 (109)**	**14.8 (369)**	**13.6 (1243)**