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THE EFFECTS OF SOCIOECONOMIC STATUS, ETHNICITY AND NUTRITIONAL STATUS ON THE GROWTH AND PHYSICAL FITNESS OF 10 YEAR OLD SOUTH AFRICAN BOYS

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by

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ABSTRACT

THE EFFECTS OF SOCIOECONOMIC STATUS, ETHNICITY, AND NUTRITIONAL STATUS ON THE GROWTH AND PHYSICAL FITNESS OF 10 YEAR OLD SOUTH AFRICAN BOYS

by

Reshma Babra Naidoo

The interrelationships among growth, physical fitness, habitual physical activity, SES, race and nutritional status of 389 ten year old South African boys attending 18 schools in the greater Johannesburg area were considered in this study. Boys were classified by race using anthroscopic appraisal, and all boys of mixed ancestry (so-called "Colored") were excluded from the sample. Boys of African (n = 208) and Indian (n = 137) ancestry were stratified into higher (n = 107, n = 99, respectively) and lower (n = 101, n = 38, respectively) SES groups. All boys of European ancestry (n=42) were classified as higher SES. Data for each subject included anthropometry, physical fitness, 3-day physical activity records, habitual physical activity questionnaires, and sociodemographic data. Nutritional status was based on body mass index and was classified as undernourished, nutritionally normal or overweight.

Race accounts for a small percentage of the variation in body proportions (sitting height/stature, 2%; and bicristal/biacromial, 4%) and fatness (sum of five skinfolds, 2%). Body mass, the sitting height/stature ratio, fatness (sum of five skinfolds) and relative fat distribution (trunk/extremity skinfold ratio) differ significantly by nutritional status when race and SES are statistically controlled. This difference may be confounded by racial variation since there are proportionally more overweight and undernourished Indian boys

compared to African or European boys. SES differences in the bicristal/biacromial ratio, mass and stature are significant when the effects of race and nutritional status are controlled, but may be confounded by race. All European boys are of higher SES.

Race accounts for a small percentage of the variation (1% to 5%) in the push-ups, 9 minute run, sit and reach, and grip strength when the effects of race and nutritional status are controlled. Nutritional status accounts for a minimal amount of the variation in the sit-ups and dash (1%), but for a larger proportion of the variance in absolute grip strength (11%) and grip strength per unit body mass (22%). SES contributes an additional 2% to the variation in absolute grip strength.

Race accounts for little of the variance in estimated energy expenditure (kcal/kg/day) in sedentary (4%) and moderate to vigorous (2%) physical activity (MVPA). There are significant nutritional status differences in MVPA and total estimated energy expenditure (kcal/kg/day) among Indian boys when the effects of SES are controlled, and in light activity for European boys.

The results of this study indicate that a relatively small proportion of variation in growth and physical fitness is related to race, whereas a significant percentage of variation in energy expenditure is associated with nutritional status. SES does not account for a significant amount of the variation in growth, physical fitness or estimated energy expenditure of 10 year old South African boys of African, Indian and European ancestry. Thus, in this sample of South African boys, most of the variation in measures of growth and physical fitness is related to factors other than race and SES.

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Chapter 1

INTRODUCTION

The change of the South African government from apartheid capitalism to a democracy in 1992, resulted in mass migration into the urban periphery, changing both the character of the urban population and the circumstances of the majority of South Africans. South African boys who turned ten years of age in 1997 have lived half of their lives under a system of apartheid capitalism and the other half under a democracy, and are an ideal example of children in a transitional society. Under apartheid capitalism, economic and social privileges were granted first on the basis of race and then by SES, creating the socioeconomic differences among the four major racial classifications in South Africa - African, Indian, the so-called "Colored" and White. In the post-apartheid South Africa, the artificial racial divides were removed, theoretically providing greater equity among the peoples of South Africa.

Growth is a plastic process and can be influenced by many environmental factors, including nutrition, socioeconomic status, geographic location, childhood diseases, and perhaps physical activity, among others. These factors may also influence physical performance and physical fitness directly or indirectly. In addition, body size, composition, proportions and physique affect strength and motor performance (Malina, 1975). Absolute and relative fat-free mass are positively correlated with strength and motor performance, while absolute and relative fat mass are negatively correlated with performance, of especially in items that require projection of the body as in runs and jumps (Clarke, 1971; Beunen et al., 1983; Malina et al., 1995).

Body size is affected by nutritional status. Negative environmental conditions result in stunted linear growth and possibly growth failure (Zeitlin, 1991; Shetty, 1993). Undernourished children have absolutely less body fat and muscle tissue compared to the well-nourished (Desai et al., 1984; Malina and Buschang, 1985; Parizkova, 1987; Spurr and Reina, 1990). There is also reasonable consensus that undernourished children score absolutely lower on tests of motor perormance, including speed, jumping, strength, distance runs, and throwing (Ghesquiere and Eeckels, 1984; Malina and Buschang, 1985; Goslin and Burden, 1986; Malina et al., 1987; Ferreira et al., 1991). Lower physical working capacity and maximal aerobic power have also been observed in undernourished children and adolescents (Satyanarayana et al., 1979; Desai et al., 1984; Spurr et al., 1991). In mild-to-marginally undernourished populations, taller and heavier boys have higher absolute physical fitness scores compared to smaller age mates, especially for static strength and physical working capacity. Most of the differences, however, disappear when scores are adjusted for body size (Ghesquiere and Eeckels, 1984; Desai et al., 1984; Malina and Buschang, 1985; Spurr et al., 1991).

Populations of the developing world have a greater reliance on child labor, and individuals often enter into the waged labor market at relatively young ages. These practices are more prevalent among children from low socioeconomic status (SES) families compared to those from higher SES families. The added burden of responsibility results in a significantly higher energy output in physical activity for boys from lower SES compared to high SES families (Post et al., 1992; Slooten et al., 1994).

The relationship between nutritional status and physical fitness may be influenced by habitual physical activity. In well-nourished populations, there is evidence to indicate that children with higher general habitual activity have a higher levels of fitness (Schmucker, 1984; Dotson and Ross, 1985; Mirwald and Bailey, 1986; Sunnegardh and Bratteby, 1987; Pate et al., 1990). In undernourished populations, habitual physical activity also appears to be related to physical fitness (Sloan and Hansen, 1969; Goslin and Burden, 1986) and working capacity (Satyanarayana et al., 1979; Desai et al., 1984), but the intensity of the habitual physical activity is probably a greater determining factor of physical fitness among undernourished populations (Wyndham, 1973; Goslin and Burden, 1986) than frequency and duration of habitual physical activity.

The factors affecting growth, physical fitness and physical activity of children are multiple and interacting. This study addresses the effects of SES, race and nutritional status on the growth, physical fitness and physical activity of 10 year old South African boys.

Purposes

The purpose of this study is to investigate the effects of SES, ethnicity (race), and nutritional status on the growth, physical fitness and physical activity of 10 year old South African boys of European, African and Indian ancestry.

Research Question

The study examines the following question:

What is the relationship of socioeconomic status, race, and nutritional status to growth status, physical fitness and habitual physical activity of 10 year old South African boys?

Research Questions

The following research questions were tested:

1. Are there significant SES, race and nutritional status differences in the growth status of 10 year old South African boys?
2. Are there significant SES, race and nutritional status differences in the health- and performance-related physical fitness of 10 year old South African boys?
3. Are there significant SES, race and nutritional status differences in the habitual physical activity of 10 year old South African boys?
4. Are there significant nutritional status differences in race-specific habitual physical activity of 10 year old South African boys?
5. Are there significant race-specific differences in the growth status and physical fitness of 10 year old South African boys of African, Indian and European ancestry with different levels of estimated energy expenditure?

Definition of terms

Adolescent encompasses all individuals between 10 to 19 years of age (World Health Organization, 1995).

Family is a term that is used loosely. There has been a considerable eroding in the nuclear family in South Africa. The term family is used to describe the group of people with whom the child lives. This group could be a collection of older relatives, friends, grandparents and/or other unrelated individuals. The continued low-scale civil war over the last decade has eroded conventional family life in many African families and has made it necessary to redefine the traditional family in the South African context.

Growth is an increase in size of the body as a whole or of specific parts, due to changes in cellular processes that include hyperplasia, hypertrophy, and accretion (Malina and Bouchard, 1991).

Habitual physical activity is the amount of physical activity that the child normally performs in his regular daily schedule. **Physical activity** is "any body movement produced by the skeletal muscles that results in a substantial increase over the resting energy expenditure" (Bouchard and Shephard, 1994, p. 77). This definition of physical activity includes physical leisure, exercise, sport, occupational work and chores, and other factors that modify the total daily energy expenditure.

Health-related physical fitness is a state characterized by an ability to perform daily activities with vigor and demonstrate traits and capacities that are associated with low risk of premature development of the hypokinetic diseases (Pate, 1988). It is operationalized as body composition (subcutaneous fatness), cardiorespiratory endurance

(9 minute run), and musculoskeletal function (sit and reach, push-ups and sit-ups) (AAPHERD, 1984).

Malnutrition is defined as a body mass index (BMI)-for-age below the 5th percentile (undernutrition) or at the 85th percentile and above (overweight) of the NCHS/WHO reference data (World Health Organization, 1995).

Performance-related physical fitness is an indication of the attained levels of motor performance. Static strength (grip strength), agility (50 meter shuttle run), running speed (50 meter dash) and explosive power (standing long jump) are components of performance-related fitness.

Race is a variably defined concept. In South Africa, there are four major racial classifications by the Nationalist Government: African (of African ancestry), Indian (of Indian Ancestry), White (of European ancestry), and so-called "Colored" for people of mixed ancestry (International Defense and Aid Fund, 1991). Race is a biological referent while **ethnicity** is a cultural referent (Smaje, 1996). In this study, race is used interchangeably with ethnicity since there is little distinction between race and ethnicity in South Africa. The Group Areas Act and Color Bar Acts in South Africa have minimized the differences between these concepts.

Sociodemographic status (SDS) is the combination of socioeconomic status (SES) and race. SES is a reflection of the social and economic circumstances of the individual and his family. The education, income, and occupation of the head of the household, and the occupancy ratio (number of people per room in the home) are indicators that affect the SES of the individual. The individual is placed in an SES category based on the cumulative score of education, income and occupational prestige of the head of the household.

Limitations

1. The most accurate measures of the energy intake and expenditure of an individual in field studies use weighing and recording of all food consumed, and recording of all physical activities of the individual. These are time consuming and labor intensive procedures that require well trained personnel to weigh, calculate and record the amount of food consumed and to estimate its composition, as well as to observe and record all physical activity. These methods were not available for this study.

Waterlow et al. (1977) recommend that weight-for-height be used as the primary indicator of present nutritional status and height-for-age as an indicator of past nutrition for the assessment of the nutritional status in cross-sectional studies of children under 10 years of age. While the relationship of weight and height is reasonably stable during childhood, there are maturational status differences in body weight and stature during adolescence. Thus, at a given height, the weight corresponding to a particular percentile is not the same for all ages. The meaning of weight-for-height differs with each age.

The recent guidelines on anthropometry issued by the World Health Organization, (WHO, 1995) advise the use of the body mass index (BMI) for age as a proxy for nutritional status. The BMI has high specificity (99%) and efficiency (89%) in overall correctness in classification of obesity. However, it has low sensitivity (29%) as an indicator of obesity in adolescent boys (Himes and Bouchard, 1989). On the other hand, the specificity, efficiency and sensitivity of the BMI as an indicator of thinness or undernutrition has not been estimated, but low BMI values are reported for undernourished adults (Desai et al., 1984; Spurr, 1987; Satyanarayana et al., 1989; Giay and Khoi, 1991; Naidu and Rao, 1994).

The WHO Expert Committee recommended the provisional use of the U.S. reference data of Must et al. (1991) for the BMI until better reference data for adolescence are available. The recommendations are based on the following strengths: (1) sampling weights were appropriately used in calculating the national estimates, (2) percentiles recommended for cut-offs were presented, and (3) percentiles were smoothed mathematically across ages in an acceptable manner (WHO, 1995).

2. The use of heart rate monitors would increase the accuracy of the measurement of the physical activity. Monitors were not available for this field study. The estimate of physical activity was based on 3-day activity records maintained by the subjects. The activity records provided an indication of involvement in light, moderate and heavy physical activity. Daily energy expenditure and detailed accounts of physical activity were not attained using the 24-hour recall records. The recall records provided an indication of the trends in the habitual physical activity of subjects.

Recall surveys are subject to memory decay, social desirability, interpretation of the questions, and the ability of the interviewer in providing memory enhancing triggers. The ability of 10 year old South African boys to complete recall records may be affected by their concept of time and awareness of the intensity and length of an activity. These potential problems are major limitations. The use of memory triggers and estimates of time were provided to assist in the recall. However, these limitations are inherent in the methodology employed and have to be accounted for in the interpretation of data.

3. The health- and performance-related physical fitness of subjects were estimated from scores on a battery of tests. Culture, nutritional status, health, and motivation influence performance on such tests. While efforts were made to increase the arousal and motivation of the subjects to perform at their best, understanding of the word "maximum" may have been a limiting factor.

4. No indicators of maturity status were used. It is assumed that most boys in the sample were prepubescent. However, some boys from the upper SES samples may have been in the early stage of puberty.

5. A convenience sample of volunteers from Government, Model-C and private schools was used in this study. The potential school effect biases in the sample were not considered.

6. While growth status is a combination of past and current nutritional history, there was no control for the nutritional history of subjects.

7. The ongoing low scale civil war in South Africa introduces stressors that influence the development and maturation of children. These factors, however, fall outside the scope of this study.

Scope of Study

This study looks at the complexity of factors that affect the growth status and physical fitness of 10 year old South African school boys from the greater Johannesburg area (Guateng). The relationship of SES, race and nutritional status to growth and physical fitness are considered. SES and demographic factors play an important role in identifying and explaining components that impact the growth and physical fitness of an individual. The relationship of SES, race, and nutritional status to growth, physical fitness and physical activity contribute to the understanding of factors that affect the growth and physical fitness of children.

Significance of Study

This study addresses the relationship of SES, race and nutritional status to the growth status, health-related and performance-related physical fitness, and habitual physical activity of 10 year old South African boys of African, Indian and European ancestry. The effects of SES, race and nutrition and their interactions have direct and indirect impacts on growth status and physical fitness. The complexity of factors that impact on growth is well documented (Ijsselmuiden, 1984; Richardson and Sinwell, 1984; Chaning-Pearce and Solomon, 1986; Cameron et al., 1988a; Cameron, 1991). Several studies have addressed aspects of SES, race, nutritional status, growth and physical fitness relationships of South African children. These include, for example, nutritional status and physical fitness (Sloan and Hansen, 1969), ethnic variation and physical fitness (Sloan, 1966a, 1966b), and performance (Kelder, 1984), physical fitness and growth status (Smit, 1969; Henneberg et al., 1987), and the efficacy of enriched physical activity programs on the growth and physical fitness of low SES children (Van Rooyen, 1994).

South Africa is undergoing significant transitions in the 1990s (IDAF, 1991). There has been a major urban-rural shift in recent years (Hindson et al., 1994). The desegregation of population groups and restoration of rights and privileges to previously disenfranchised populations has created a complexity of environmental dynamics. Thus, examination of the growth and physical fitness of children in a transitional society may provide a unique perspective o the transition.

Race and SES are closely aligned in South Africa (IDAF, 1991). Physical activity and nutritional status are influenced by cultural and religious practices. Therefore, focusing on the individual and combined effects of the SES-race couplet is necessary to tease out individual contributions to the growth status and physical fitness of 10 year old South African boys. Boys who turned ten years of age in 1997 would have spent the first half of their lives under a system of apartheid capitalism and the latter half under a system of democracy, and provide a good example of children in a transitional society.

Chapter 2

REVIEW OF LITERATURE

The literature review is divided into three parts. The first presents an overview of South Africa to contextualize the sociopolitical environment and to provide insight into the dynamics that determine and define socioeconomic status (SES), race or ethnicity, and nutritional status. The second part focuses on SES, race or ethnicity and nutrition in studies of human growth. In the third part, the relationship of SES, race or ethnicity and nutrition with physical fitness is examined; the relationship of habitual physical activity, energy balance, growth and physical fitness is also considered.

South Africa: geographic, demographic and sociopolitical background

South Africa spans the southern tip of the African continent. It covers an area of 1,221,040 km^2 (472,359 miles). It is mostly semi-arid, but is subtropical along the east coast. The sociopolitical and economic climate of South Africa is a mixture of the apartheid capitalism of previous years and its newly won democracy.

South Africa formally endorsed the policies of apartheid from 1910 with the enactment of the Land Act of 1910 until the democratic elections of 1994. Enforcing apartheid in South Africa was made possible by the enactment of laws that clearly defined the boundaries of racial integration. The Prohibition of Mixed Marriages Act

(1949) and the Immorality Act (1950) made mixed marriages and sexual intercourse between Europeans and Blacks illegal. The Population Registration Act (1950) classified the population into four major racial groups.

White was used to define anyone who obviously looked European but was not generally accepted as a "Colored" person, and included all people of European ancestry (Riley, 1991). The term Black was used to group people of any aboriginal tribe of Africa, hereafter referred to as African (Riley, 1991). The term "Colored" was a broad classification that included only those of mixed descent in terms of the racial classifications of the country and people of Malaysian, Khoi, and San descent. They are hereafter, referred to as so-called "Coloreds" (IDAF, 1991). People of Indian and Middle Eastern ancestry were classified as Indian (IDAF, 1991). The proportion of people of Middle Eastern ancestry classified as Indian is unknown.

The Pass Laws of August 1966 made it compulsory for all people over the age of 16 to possess, carry and produce identity cards at the request of an authorized person (UNESCO, 1974). The Pass Laws were part of the influx control measures and were used to minimize the number of Africans in White South Africa. The Bantu Self-Government Bill (1959) provided for the establishment of eight national units and was used to transform former African reserves into self-governing homelands with limited legislative authority (Riley, 1991). Bantustan Homelands were the only areas in which Africans were legally permitted to own land. Residence in these homelands was based on tribal affiliations and served to increase inter-tribal conflict. Township residence was restricted to those actively engaged in waged labor (IDAF, 1991).

The political economy of South Africa was one of apartheid capitalism where race and class defined access to, and ownership of, power in South Africa. In apartheid capitalism, the wealth and resources of the country were distributed on a sliding scale where the interaction of race and class determined access to wealth and power. Apartheid capitalism of South Africa created a society in which minimal distinction between class and race existed (UNESCO, 1974). The economy of South Africa was made to fit the imperatives of the racial political system and was done by controlling the labor market, and exercising monopoly control and racial exclusiveness over skilled jobs (Wolpe, 1987).

Education was stratified along the lines of race (Bantu Education Act, 1953; "Colored" People's Education Act, 1963; Indian's Education Act, 1965) to provide for the different sectors of the labor market (UNESCO, 1974). This stratification was the basis of apartheid capitalism. European education was designed to produce the leaders in the community and African education to provide unskilled manual laborers. This segregation was further enforced by forbidding Blacks, mainly Africans, from filling certain skilled jobs. Africans thus provided the pool of cheap unskilled and semi-skilled labor which formed the basis of the economy (UNESCO, 1974). Urban Africans were predominantly employed in the mines and industries, while the majority of rural Africans were employed by European farmers (UNESCO, 1974). Indian education, on the other hand, was designed to produce skilled, semi-skilled, clerical and professional labor, and lower to middle management (UNESCO, 1974).

Under the apartheid laws, Europeans were legal or first class citizens of the country. Africans, "Coloreds" and Indians were second class citizens of the country. Suffrage, compulsory and free education, access to public health care, and choosing where to live were the rights of first class citizens, which were denied to second class citizens. The Group Areas Act (1950), which restricted residence to racially designated areas, was pivotal in maintaining the status quo in South Africa (Riley, 1991).

Similar inequalities were expressed in all aspects of civil life. The majority of the resources in the country were spent on provisions for Europeans (Table 1). Thus, while a relatively small proportion (2.2%) of the GNP was spent on health care compared to other countries in the region, a 6.3-fold greater per capita health care expenditure was made for Europeans ($146) than for Africans ($23.75) (Henry J. Kaiser Family Foundation, 1991).

Table 1. Basic indicators of health status in South Africa.[a]

Indicator and year	African	European	"Colored"	Indians
Population (million), 1996[b]	32.2	5.2	3.5	1.1
Percentage of population	76.7	12.4	8.4	2.5
Infant mortality, per 1000 liveborn, 1988	80.0	11.9	46.3	19.0
Percentage of population < under 5, 1988	15.9	7.9	11.9	10.3
Per capita health expenditure, 1987[c]	$15.57 (R95)	$97.70 (R596)	$55.57 (R339)	$58.36 (R356)
Per capita educational expenditure, 1988[c]	$45.25 (R276)	$504.92 (R3,080)	$227.05 (R1,385)	$364.92 (R2,226)
Life expectancy, 1985	62	71	61	67
Life expectancy, 1996-2001	64.5	73.6	64.4	70.2
Percentage of all deaths < 1 year, 1987	15.7	1.3	10.8	5.4
Percentage of all deaths < 5 years, 1987	22.5	2.1	16.3	7.3

[a]Adapted from Henry J. Kaiser Family Foundation (1991, p.10).
[b]From South Africa Survey 1996/7 (Sidiropoulos et al., 1997, p.8).
[c]Based on the rand-dollar exchange rate of six rand and ten cents (R6.10) to one $1.

The abolition of the Influx Control Act (1986) (IDAF, 1991), discontentment with the political and economic conditions, an ongoing drought from 1984 to 1994 (Hindson et al., 1994), and the removal of the Group Areas Act (1991) led to considerable resettlement in South Africa. The removal of the Group Areas Act made it possible for the majority of South Africans to choose where they lived. Large numbers of people moved out of the impoverished homelands into urban areas in search of employment (IDAF, 1991). There was considerable relocation between residential suburbs. Additionally, peri-urban squatter settlements grew rapidly (Hindson et al., 1994).

Major changes in the political economy and social conditions, subject to SES, of South African populations occurred in the past 10 years (Table 2). In the ten years from 1985 to 1994, there was a 12.8% increase in personal disposable income, with race specific increases of more than 35% for Africans and 24% for Indians, and a decrease of 2.5% for Europeans (Sidiropoulos et al., 1997). The Human Development Index (HDI) of the United Nations is a measure of socioeconomic development and is a composite of life expectancy, per capita income and the level of education. Between 1980 and 1991, Africans in South Africa moved from a low HDI of 0.394 to a medium level of 0.500. Both Europeans and Indians moved from a medium (0.739 and 0.655, respectively) to a high (0.901 and 0.836, respectively) level of human development, indicating an improved quality of life for all groups.

Unemployment, however, is high. It is currently estimated that 29% of the economically active sector is unemployed (Sidiropoulos et al.,.1997). In Gauteng, 20.9%

of the economically active population was unemployed in 1995 (Sidiropoulos et al., 1997). Despite the change in the hegemony, there are large race differences in unemployment rates. African women (46.3%) and men (28.9%) have the highest, and European males (3.7%) and females (8.3%) have the lowest unemployment rates. In 1995, 87% of all unemployed people were African.

Table 2. Relative changes in the economic status of South Africa over the last decade.[a]

	African	Indian	European	"Colored"	Total
Personal disposable income[b]	35%	24%	-2.5%	24%	12.8%
HDI[c]	26.9%	27.6%	21.9%	24.6%	21.5%
Unemployment rates	36.9%	13.4%	5.5%	22.3%	29.3%

[a] Extrapolated from Sidiropoulos et al. (1997).
[b] Change between 1985 to 1994 [c] Change between 1980 to 1991

There has been a rapid increase in the urbanization of South Africa. The Gauteng urban conurbation (greater Johannesburg to Pretoria) has a current population of more than 11 million. It is now the second largest metropolitan spread in Africa after Cairo and is "possibly the fastest growing emerging city in the world" (Weekly Mail, May 16, 1997). In 1995, Johannesburg was the ninth largest African city (Sidiropoulos et al., 1997). The region is characterized by mushrooming zones of informal settlements that are populated by people who are fleeing rural poverty and those who are relocating from former townships. These informal settlements are characterized by a lack of sewage facilities or rubbish removal, and do not have access to piped water.

The change in the governing policies of the country has been coupled by an unprecedented increase in crime. Statistics for 1995 indicate a dramatic increase in violent crimes over the last 21 years, with increases in individual categories being 24% for assault, 119% for murder, rape by 149%, and robbery by 171% (Sidiropoulos et al., 1997). There has been a 275% increase in theft of motor vehicles and a 223% increase in housebreaking between 1974 and 1995 (Sidiropoulos et al., 1997). Statistics for the percentage change in crimes in South Africa since the shift in government between 1994 and 1995 are not available. The number of vehicle hijackings has escalated in recent years with the 1996 (from January to August) average being 36 cars a day. Gauteng is one of the most crime ridden provinces of South Africa, with 22% of the murders, 80.7% of all car hijackings, and 26% of all rapes (Sidiropoulos et al., 1997).

Any analysis of health and development in South Africa must take into account the fluidity of its population. The majority of African children are newly arrived from homelands, townships, rural and peri-urban areas (Hindson et al., 1994), and bring with them a social, nutritional and cultural history. Thus, a contextual analysis which incorporates the rural, peri-urban and urban populations is necessary to understand the factors that affect the status of the population.

A sample of boys who turned 10 years of age in 1997 are survivors of the apartheid era in South Africa. The Group Areas Act (legal enforcement of racially segregated residential areas) and the Color Bar Act (legal prohibition of interracial marriages or cohabitation) enforced by the apartheid government presented a barrier to racial admixture. These boys experienced the privileges (for Europeans) and disenfrancement (for people of color but especially Africans) that the apartheid policies of South Africa enforced for the first 6 years of their lives. Despite the removal of the Color Bar Act in 1982, the Group Areas Act (abolished in 1991) served to control interracial marriages and cohabitation.

The diversity of the South African population is large and includes the geographical divide which banished Africans to barren and harsh climes. Additionally, the Color Bar and Group Areas Acts limited racial admixture. Thus, the South African population presents an opportunity to look at the effects of race, culture and SES on growth and development of a diverse group of children within the same country. Boys of African, European and Indian ancestry who turned 10 years of age in 1997 present a sample with clearly different SES histories and circumstances.

Summary

South Africa has a population that has been traditionally classified into three racial groups of African, Indian and European, with people of mixed ancestry classified as the so-called "Colored" by the Colonialists and the former government. Racial classification by the former government was limited to four groups that were arbitrarily assigned using broad visual criteria. The political economy of the country created a society that is stratified in terms of SES (largely defined by race) with a large working class and a small middle class. The working class and lower SES groups have maintained cultural homogeneity, while the middle class were products of English mission education and assimilated the culture of the English (Archer and Bouillon, 1982).

The current status of South Africans is the legacy of apartheid, rapid urbanization, proliferation of peri-urban squatter settlements, high prevalence rates of HIV infection and AIDS (McItyre, 1996), high unemployment rates, high rates of illiteracy, single parent families and orphaned children. Unequal education, inequity in the power sharing and decision making processes, and the oppression of the majority of the people in South Africa created a society with large differences in living standards. Despite the change in the political climate of South Africa, the majority of South Africans have not benefited from these changes.

Growth and physique

It is well established that children in the developing world are shorter and lighter, and mature later, on average, than children in developed world populations (Eveleth and Tanner, 1976, 1990; Cameron, 1991). Poverty (Martorell, 1982), culture (Gopalan, 1992), malnutrition and infectious disease (Mata, 1972; Stephenson et al., 1991, 1993) are perhaps among the major environmental factors that affect the growth of children in the developing world.

Stunting, or linear growth retardation, depends on SES, maternal nutrition and health status, and the educational level of the family (Waterlow, 1994). The main causes of stunting are insufficient or inadequate prenatal and/or postnatal energy and nutrient supply (Martorell, 1993), increased prevalence of infection (Mata, 1972; Stephenson et al., 1991), altered fetal growth, (Allen and Uauy, 1994) and mother-child interaction (Chavez and Martinez, 1984; Waterlow, 1994). Genetic transmission, congenital or environmental factors, maternal disease or nutritional deficits, and maternal malnutrition affect linear growth in utero (Allen and Uauy, 1994).

Nutrition and poverty in South Africa

The nutritional status of people reflects, to a large extent, the poverty level of a country. In South Africa, the majority of the African population lives in conditions where basic survival needs are often unmet or only marginally met (Henry J. Kaiser Family Foundation, 1991). Preventable communicable diseases and malnutrition affect most populations in rural areas and informal settlements in the peri-urban areas (Henry J. Kaiser Family Foundation, 1991; Hindson et al., 1994). Poor health situations are due to the lack of sanitation, clean water supplies, and waste removal services; crowding; and the public health infrastructure. The increased incidence and prevalence of respiratory infections are attributable in part to the use of kerosene, coal and anthracite as fuel (Yach, 1988).

African and "Colored" children are 14 to 15 times more likely to die before the age of 5 than European children, and over 200,000 African children were wasted, with low weight-for-height in the 1980's (UNICEF, 1987). Differences in poverty levels by race, age, and urban-rural status affect the nutritional status of the total population (Table 3). More recent birth to 5 data has not been reported.

Table 3. Prevalence of stunting, underweight and wasting in children by ethnicity.

	African				
	Urban	Rural	"Colored"	Indian	European
1 to 5 years of age[a]					
Stunting (90% height-for-age)	11.7	40.9	18.6	6.4	3.7
Underweight (80% weight-for-age)	28.2	42.7	48.6	35.0	15.6
Wasting (80% weight-for-height)	6.9	3.0	11.3	14.5	7.5
6 to 12 years of age[b]					
Weight-for-age	22.2		24.7	17.8	3.8

[a] Adapted from Wyndham (1986, p.281), based on the NCHS reference data.
[b] Adapted from The Department of National Health and Population Development (1990); criterion for reference data was not indicated.

It is currently estimated that 2.3 million (17.4%) people of the total population in South Africa are malnourished (Ministry for Welfare and Population Development, 1995). However, the criterion for malnutrition was not specified.

SES is a strong determinant of growth status in most populations. Cernerud (1993) found associations between the father's occupation level and the height of 10 year old children from Stockholm and the number of inhabitants per room. Other data (Desai et al., 1984; Chaning-Pearce and Solomon, 1986; Satyanarayana et al., 1989; Bogin et al., 1992; Cameron and Kgamphe, 1993) indicate differences in height and weight, and body composition between children of upper and lower SES in several areas. In countries where ethnicity (race) is closely tied with SES, the distinction between SES and ethnicity is unclear. The interrelationship between SES and race has been noted in England (Rona and Chinn, 1986), Guatemala (Bogin et al., 1992), the United States (Joe, 1987), Zaire (Ghesquiere and Eeckels, 1984), and South Africa (Sloan and Hansen, 1969; Richardson, 1978; Chaning-Pearce and Solomon, 1986). People of European ancestry in both Europe and developing world populations are generally of higher SES compared to non-European populations. Furthermore, in developing world countries, aboriginal populations are generally of lower SES compared to immigrant populations.

The relationship between SES and growth is not always linear. In environments with a high prevalence of malnutrition, stunting and illness among children, some children demonstrate a 'positive deviance' by growing and developing adequately despite the poor environmental conditions (Zeitlin, 1991). Personal and household hygiene, the preparation and storage of food, and handling of water are amongst the factors that are responsible for the "positive deviance. (Martorell, 1982; Zeitlin, 1991).

Cultural practice associated with food and eating influence the energy and nutrient content of the meal. Preferential feeding patterns in families that favor certain individuals within the family can alter the SES-nutrition relationship and produce nutritional status differences between individuals within the same family. Preferential feeding of males is a common practice in cultures that favor male offspring. Birth order and spacing, gender, and age are factors which determine sharing and portioning of food (Dugdale, 1985). Cultural food taboos also affect nutritional status. Religious customs, such as vegetarianism as practiced in some forms of Hinduism and the prolonged periods of food abstinence (mandated for all healthy adults and most school-aged children) during Ramadaan as a discipline of Islam, may affect the nutritional status of children and adults.

Nutrition and growth

The assessment of the nutritional status of an individual or population includes dietary history, physical examination, anthropometry, body composition, and biochemical analyses (Spurr, 1983a). Undernutrition is defined as "measurable changes in nutritional status that result from a chronic marginal deficit of food quality and or quantity" (Allen, 1994, p. 924). It is generally accepted that malnutrition in developing countries is largely due to caloric or energy insufficiency (FAO, 1987).

The severity of the physiological effects of malnutrition can range from mild to severe and are due to the interaction of intensity, duration and timing of the stress (Malina, 1985). Social, cultural, economic and political factors; and parasitic and infectious diseases are several interrelated contributors to undernutrition (Ferreira, et al., 1991). Mild-to-moderate manifestations are a result of chronic early childhood exposure to the stress of undernutrition. Characteristic features of undernutrition are stunted growth, delayed biological maturation, reduced muscle mass, and decreased physical working capacity (Spurr, 1983; Malina, 1984, 1985; Malina and Buschang, 1985; Johnston et al., 1985), retardation of functional and cognitive development (Chase and Martin, 1970; Chavez and Martinez, 1979; Allen, 1990; Pollitt et al., 1993, 1995; Wachs, 1995), reduced levels of physical activity (Adams et al., 1994), impaired resistance to infection (Frank and Zeisel, 1988), increased morbidity and disabilities, and eventually death (Food Nutrition and Agriculture, 1992). Marginal undernutrition is more prevalent than severe undernutrition in developing countries; severe undernutrition presents itself as marasmus, kwashiorkor or an undifferentiated form (Allen, 1993).

Anthropometric assessment of nutritional status includes weight-for-age (underweight), height-for-age (stunting), weight-for-height (wasting), BMI-for-age (thinness and overweight), and the triceps and subscapular skinfolds (WHO, 1995). Chronic and persistent undernutrition is characterized by low weight-for-height and low height-for-age (WHO, 1995) based on reference data for American children and youth (Table 4).

Table 4. Recommended cut-off values for adolescents.[a,b]

Indicator	Anthropometric variable	cutoff values
Stunting	Height-for-age	< 3rd percentile or < -2 Z-score
Thinness	BMI-for-age	< 5th percentile
Obesity	BMI-for-age Triceps skinfold (S_t) Subscapular skinfold (S_s)	≥ 85th percentile for BMI, ≥ 90th percentile for S_t ≥ 90th percentile for S_s

[a]Adapted from WHO (1995, p. 271)
[b]Adolescents are defined as youth between 10 and 19 years of age.

Weight-for-age and height-for-age were the previously recommended anthropometric indicators for the nutritional status of adolescents, defined as 10 to 19 years of age (WHO, 1995). However, potential maturity-associated variation in body size make the reference data awkward to use without adequate control. The BMI-for-age is currently recommended as the indicator for assessing nutritional status in adolescents (WHO, 1995). The correlation between BMI and total body fat is 0.90, and between BMI and percentage body fat is 0.68 in boys 6 to 12 years of age, using underwater weighing (Siri Equation) to estimate density and fatness (Roche et al., 1981). The BMI was the best indicator of total body fat, but a poorer estimate of percentage body fat compared to relative weight, weight /stature^3, and the triceps, subscapular and suprailiac skinfolds (Roche et al., 1981).

BMI percentiles based on NHANES I have been estimated by at least three sets of independent researchers (Hammer et al., 1991; Must et al., 1991; Cronk and Roche, 1982). Hammer et al. (1991) limited their analysis to Whites only. Cronk and Roche (1982) analyzed the data for the 6 to 50 year old population and estimated the BMI for Blacks and Whites separately. Must et al. (1991) analyzed the data for Blacks and Whites separately, but also presented BMI values for the total population.

Different weighting techniques were used by Cronk and Roche (1982) and Must et al. (1991a). Cronk and Roche (1982) smoothed all percentile values using low term Fourier transforms. The terms chosen for smoothing were based on the goodness of fit to the original percentile plots and the effectiveness of smoothing. The abruptness and spacing of inflection of the unsmoothed data were used to choose the number of terms. In some cases, the smoothing resulted in the 5th and 10th percentiles meeting at some ages, partly because the smoothing was done independently for each percentile. When this asymmetry occurred, the percentiles were separated by the smaller unit of the variable. Additionally, BMI percentiles for Whites and Blacks were presented separately.

Must et al. (1991) used locally weighted regression scatter-plot smoothing across percentiles for age groups. Race-specific and population-based curves for the BMI were smoothed separately, but were also presented as percentiles for the total population. These produced different BMI reference values (Table 5).

The distributions of the BMI-for-age in U.S. children (Must et al., 1991) are skewed and elevated compared to French children (Rolland-Cachera, 1991; Rolland-Cachera et al., 1993), indicating that the U.S. sample was heavier for a given height than the French sample (Table 5). Thus, U.S. percentiles are not necessarily representative of other populations. While the BMI has not been fully validated as an indicator of thinness or undernutrition in adolescents, WHO (1995) posits that it provides a single index of body mass that is applicable at both extremes.

Table 5. BMI percentiles for 10 year old U.S. and French boys.

	Percentiles						
	5th	10th	25th	50th	75th	90th	95th
Cronk and Roche (1982)[a]							
White males	14.5	14.9	15.9	17.1	18.9	21.3	23.4
Black males	14.4	15.1	15.7	16.6	17.9	21.1	23.2
Must et al. (1991)[A] - Total population	14.4	(15.2)[b]		16.8		(19.7)[c]	22.7
Rolland-Cachera (1991)	14.0	14.8	15.4	16.3	17.8	18.8	21.0

[a] NHANES I data.
[b] 15th percentile in parentheses
[c] 85th percentile in parentheses

Defining 10 year old boys as adolescent may be problematic. The mean age for entry into the early stage of puberty, genital stage 2 (G2), is 11.20 ± 1.50 years for Swiss (Largo and Prader, 1983), and 11.61 ± 1.07 years for English (Marshall and Tanner, 1970) boys. At 10 years of age approximately 16% of English and Swiss boys would be in the early stages of puberty. African South African boys from higher SES families, on the other hand, appear to be advanced in relation to poor rural African boys. The mean age of entry into G2 is 10.5 ± 2.06 years for a sample (n=152) of higher SES African boys attending fee paying private schools in Johannesburg (Cameron et al., 1993). The variation in the sample is considerable with a large standard deviation. Approximately 84% of the sample of higher SES African boys are in the early stage of puberty. Lower SES rural South African boys, however, have a mean age of 13.35 ± 2.01 years upon entry into G2 (Cameron et al., 1993). At age 10, only 2.4% of lower SES rural African boys are pubertal.

At 10 years of age, height-for-age and weight-for-age may be valid indicators of nutritional status since most 10 year old boys are probably still prepubertal. Despite limitations, the WHO (1995) advocates the BMI-for-age as an indicator of undernutrition in a population with a high prevalence of undernutrition. Additionally, population based reference data are available (Must et al., 1991a, 1991b). The BMI-for-age, however, has not been fully validated as an indicator of thinness or undernutrition in adolescents.

Indicators of health status in South African populations

Infant and Under 5 mortality

Infant and preschool mortality (1.00 to 4.99 years of age - U5) rates are accepted indicators of the health and nutritional status of a population (Martorell, 1982). There is a great disparity in the health and living conditions between urban and rural populations in South Africa, which serves to illustrate the regional differences in the health and nutritional status in South Africa.

Rural areas in South Africa have a scarcity of facilities and sanitation, lack proper food storage, and have limited access to a varied diet. These factors favor growth stunting (Little et al., 1989). The majority of the rural population in South Africa live in conditions of poverty and undernutrition, which is reflected in the infant and U5 (1.00 to 4.99 years of age) mortality rates. Infant mortality (IM) rates ranged from 48 to 151 per 1000 liveborn in rural villages in northern South Africa in the 1970s and 1980s (Richardson and Sinwell, 1984), and remained high (88 per 1000 liveborn) in the late 1980s (Koumans, 1992). Irwig and Ingle (1984) reported an U5 mortality rate of 190 per 1000 population in rural Transkei (a homeland), whereas IM for African South Africans was 80 per 1000 liveborn in the same period (Henry J. Kaiser Family Foundation, 1991). More recent data with a breakdown of urban and rural infant mortality rates are not available. The combined urban and rural IM rates were 52/1000 liveborn with an U5 mortality rate of 69/1000 population (World Bank, 1995). In Northern Transvaal, 15% of annual admissions and 28% of all deaths at the Elim hospital, which serves Venda and Gazankulu (homelands), are primarily due to undernutrition (Ijsselmuiden, 1984).

High rates of stunting and wasting are reported in infants and children in the rural homeland populations of South Africa (Shuenyane et al., 1977; Ijsselmuiden, 1984; Richardson and Sinwell, 1984; de Villiers, 1987). Issjelmuiden (1984) and Richardson (1986) report that one-third or more of the rural U5 population are underweight (32.3% < 3rd percentile for weight-for-age, and 42.7% < 80% weight-for-age, respectively). However, only 28.2% of urban U5 African boys are underweight (<80% weight-for-age)

(Richardson, 1986). A higher proportion of rural (40.9%) compared to urban (11.7%) U5 boys are stunted (< 90% height-for-age) (Richardson, 1986).

Children and Adolescents

Studies of growth status of children and adolescents in South Africa have several limitations. Data are generally presented only graphically. Although the majority of studies use the NCHS (U.S.) reference data, some use British reference data. Criteria for defining stunting and wasting range between 80% to 90% of reference values, and < 5th or < 3rd percentiles. Thus, direct comparisons are often limited. Many of the studies included in this review are based on extrapolations from graphs. Mean values are plotted and in most cases, the range, standard deviations and/or standard errors are not indicated. Some researchers (Leary, 1968; Walker and Walker, 1977; Cameron and Kgamphe, 1993) do not indicate the method used to specify age groups or to determine age. Ten years of age may include children between 9.5 to 10.4 years, with a mean of about 10.00 years, or between 10.00 and 10.99 years of age, with a mean of about 10.5 years. Additionally, the accuracy of reported birth dates and thus ages may further confound comparisons. Data intrapolated from graphs are for 10.5 years of age.

This review includes 31 samples: 11 rural African, 7 urban African (one sample of African school children did not distinguish between urban and rural status, Kotze et al., 1986), 6 urban European, 3 urban Indian, and 4 urban "Colored". Populations of "Colored", Indian, and European ancestry are underrepresented. Additionally, 7 of the samples are from the same study. The two samples of Tswana boys are from Botswana, but are included in this review since the Tswana are split across the South Africa-

Botswana border. Two studies (Richardson, 1978; Kotze et al., 1986) present data on a cross-section of South African children. Richardson (1977, 1978) compiled growth charts based on data from other studies. Kotze et al. (1986) present data from a survey of 24,426 South African school children randomly selected in 1981. Additionally, the majority of the studies were conducted in the 1970s, and considerable sociopolitical changes have taken place since.

Growth status of South African children and adolescents

On average, rural African populations (both male and female) in South Africa are shorter and lighter, age for age than urban African children (Walker and Walker, 1977; Richardson, 1978; Wagstaff et al., 1987). Similar urban-rural differences in stature and mass occur in Namibia (Jooste et al., 1992). However, urban-rural differences are not evident across all South African groups, with greater variability among means with urban and rural samples (Table 6). Some studies (Leary, 1968; Walker and Walker, 1977; Badenhorst et al., 1992; Cameron and Kgamphe, 1993) indicate that rural samples are taller and heavier than urban samples (Wagstaff et al., 1987). Sampling and cohort variation are confounding factors. Corlett and Woollard (1988), on the other hand, report taller stature in Tswana children 7 to 14 years of age from rural (Kgalagadi) compared to urban (Gabarone) Botswana. However, urban Tswana children are shorter than the NCHS reference data (Corlett, 1986). The children from Kgalagadi (rural) have significantly lower body weights than the urban sample.

Approximately 76.5% of all rural Africans (South Africa) lived in former homelands in 1990 (Henry J. Kaiser Family Foundation, 1991). These areas are characterized by forced relocation, overcrowding and lack of economic opportunity. The inhabitants of homelands are primarily women, children and the elderly (Henry J. Kaiser Family Foundation, 1991).

Urban-rural differences in growth are confounded by SES, the economic status of an individual within the society in which he/she resides. A major limitation in comparing SES across studies is definition. SES does not have a universal singular indicator, and commonly used indicators such as occupational prestige, area of residence, education of parents and household income do not necessarily indicate the SES of individuals within their society or the same thing in different societies. The use of a composite SES score that includes several of the indicators of SES may increase the accuracy of the classification. A singular indicator of SES, such as the possession of electronic equipment or the ownership of a drivers license, is used but their meanings may differ across urban and rural, or developed compared to developing world populations. Additionally, the definition of urban and rural may differ. The comparison of SES across studies must account for the definition of SES.

Most rural African populations are of lower SES compared to urban African populations. However, the relationship between SES and growth is not always positive and linear. For example, Cameron and Kgamphe (1993) did not observe a relationship between SES and growth in two South African rural populations. These authors compared the growth of a sample of male and female Zulu from Ubombo and North Sotho/Pedi from Vaalwater, 6 to 18 years of age. Despite the instability and seasonality of food supply of the Ubombo compared to the Vaalwater sample, the men were consistently taller, heavier and fatter than the Vaalwater sample. The Ubombo sample were also the tallest, heaviest and fattest African children compared to samples from rural Botswana (Corlett and Woollard, 1988), pastoralists and rural Kenyans, and average urban children from Soweto (Wagstaff et al., 1987). Ubombo youth have, on average, larger subscapular and triceps skinfolds, and arm circumferences, and are heavier and taller compared to the Vaalwater youth. Cameron et al. (1992) argue that these differences in the morphology between the Northern Sotho/Pedi (Vaalwater) and Zulu (Ubombo) may reflect major dietary differences, and posit that the Northern Sotho/Pedi children exhibit a marasmic 'line of development' which is characterized by low fat and low muscle. On the other hand, they suggest that Zulu children show a kwashiorkor 'line of development' which is exemplified by high fat and low muscle. Cameron et al. (1992) postulate that the observed differences in the morphology of the Ubombo and Vaalwater samples could reflect genetic variation in subcutaneous fat distribution.

Samples from 1967 and 1993 were compared to evaluate the growth status of South African populations over the past 25 years (Table 6). This raised the question if some of the differences in stature and mass are related to secular changes in urban populations. There is no evidence of secular change in the rural African population over the last 25 years. With the exception of the sample of Badenhorst et al. (1992), there is a general negative trend in the heights of 10 year old rural African populations (Figure 1), while there is a slight positive trend in the heights of urban populations from 1967 to 1986.

Table 6. Mean heights, weights and estimated BMI from selected samples of 10 year old South African boys.

	Height (cm)	Weight (kg)	BMI ($kg.m^{-2}$)[a]
Rural African			
Pedi (Leary, 1968)	137.8	29.4	15.5
Bochem - 1976 (Walker and Walker, 1977)	131.5	27.2	15.7
Komatipoort - 1974 (Walker and Walker, 1977)	137.9	30.6	16.1
Letaba - 1975 (Walker and Walker, 1977)	132.7	27.5	15.6
Rustenburg - 1975 (Walker and Walker, 1977)	129.3	25.6	15.3
Saulspoort - 1975 (Walker and Walker, 1977)	131.0	28.3	16.5
Richardson (1978)[b]	128.0	23.0	14.0
Tswana (Corlett and Woollard, 1988)	129.2	25.3	15.2
Johannesburg (Badenhorst et al., 1992)	140.7	31.4	15.9
Ubombo - 1985-1986 (Cameron and Kgamphe, 1993)	132.5	28.0	15.9
Vaalwater - 1985-1986 (Cameron and Kgamphe, 1993)	130.5	26.5	15.6
Urban African			
Pretoria - 1963 (Smit, 1969)	132.3	26.3	15.0
Soweto - 1976 (Walker and Walker, 1977)	131.8	28.8	16.6
Richardson (1978)[b]	134.0	28.5	15.9
Tswana (Corlett, 1986)	136.1	28.0	15.1
Johannesburg - 1976-1977 (Chaning-Pearce and Solomon, 1986)	131.0	29.2	17.0
Kotze et al. - 1981 (1986)[c]	131.6	27.7	15.7
Soweto (Wagstaff et al., 1987)	133.8	28.5	15.9
European			
Cape Town (Lurie and Ford, 1958)	133.1	30.4	17.2
Pretoria - 1962, 1965 (Smit, 1969)	141.3	33.2	16.6
Johannesburg - 1974 (Walker and Walker, 1977)	139.9	33.9	17.3
Richardson (1978)[b]	138.0	31.0	16.3
Johannesburg - 1976-1977 (Chaning-Pearce and Solomon, 1986)	139.0	33.3	17.2
Kotze et al. - 1981 (1986)[c]	139.9	33.4	17.1
Indians			
Pretoria - 1964 (Smit, 1969)	134.0	26.6	14.8
Richardson (1978)[b]	137.0	27.5	14.7
Kotze et al. - 1981 (1986)[c]	135.1	28.5	16.6
"Colored"			
Cape Town (Lurie and Ford, 1958)	125.6	24.1	15.3
Pretoria - 1964 (Smit, 1969)	133.2	27.6	15.2
Richardson (1978)[b]	137.0	28.5	15.2
Kotze et al.- 1981 (1986)[c]	131.6	27.8	16.1
By ethnic group[d]			
African rural	132.8	27.5	15.6
African urban	132.9	28.1	15.9
"Colored"	131.9	27.0	15.5
Indian - urban	135.4	27.5	15.0
European urban	138.5.	32.5	17.0

[a] Calculated from mean heights and weights.

[b,c] Values for both urban and rural populations drawn from across South Africa were included in these samples

[d] The ethnic group means were calculated from the reported means.

Dates when data were collected are indicated, where available

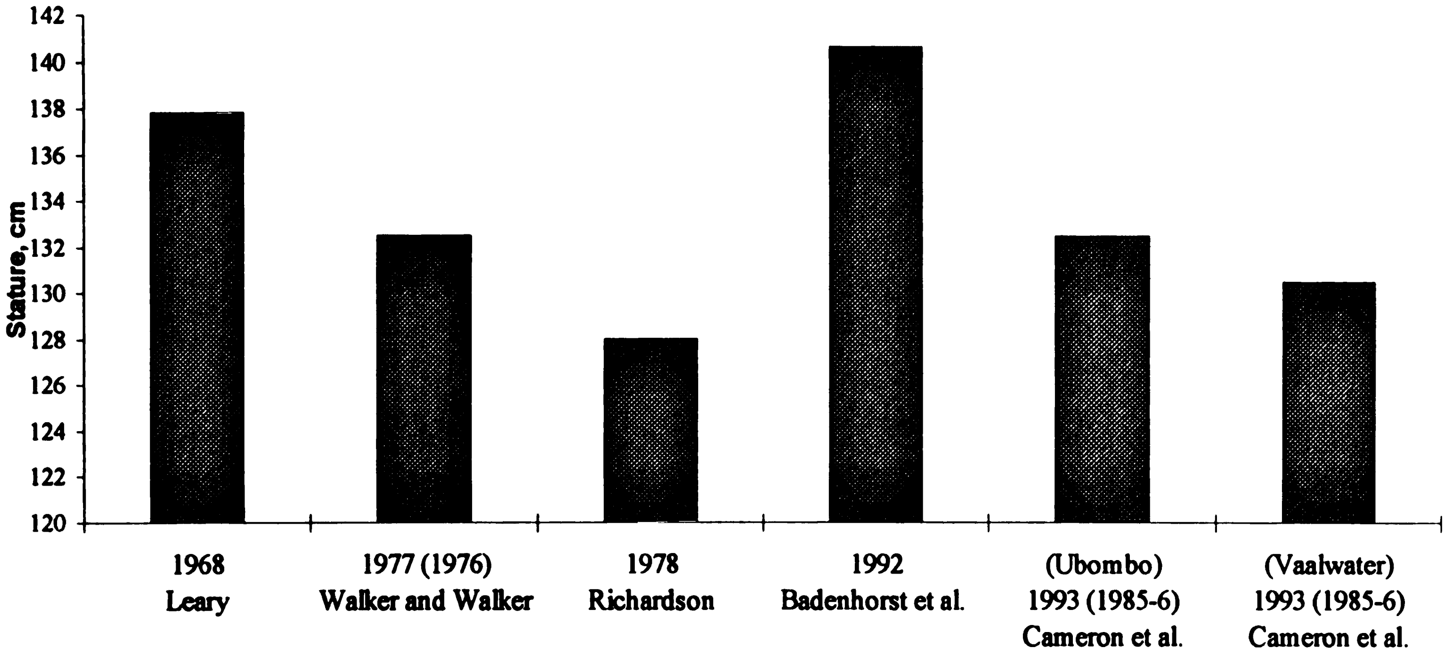

Figure 1. Stature of 10 year old rural Africans, 1968-1992. (Data in parentheses indicated the years of the survey).

The differences in the status of the 10 year old males in Soweto reported by Walker and Walker (1977) and Wagstaff et al. (1987) could indicate positive secular changes as a result of improved living conditions and infrastructure in African urban areas over the intervening 10 years. However, Tobias (1986, 1990) did not find any positive secular changes in the stature of urban adult African populations in Johannesburg. Differences in sample composition may have affected the comparisons. The data of Wagstaff et al. (1987) are for students from a lower elementary (grades 1 to 4) school in Soweto, while the data of Walker and Walker (1977) are for students of two lower elementary schools in Soweto. The wide variation in SES among people living in Soweto may contribute to the different observations made by Wagstaff et al. (1987) and Walker and Walker (1977). SES variation, in contrast to improvements in the urban infrastructure, may possibly have contributed to the difference in growth status observed in the two samples taken 10 years apart.

None of the samples of 10 year old South African boys have a mean height or weight above the 50th centile of the NCHS reference. Additionally, six samples (Smit, 1969; Walker and Walker, 1977; Richardson, 1977; Corlett and Woollard, 1988; Cameron and Kgamphe, 1993) have a mean weight that is <5th percentile of the reference. When the BMI is calculated from the mean heights and weights, one sample of South African European boys (Walker and Walker, 1977) has a BMI > 50th percentile of the NCHS reference and one sample (Richardson, 1978) has a BMI <5th percentile of the reference.

Urban African boys are slightly heavier and have a higher BMI than rural African boys. The range of variation between mean heights and weights of urban and rural African samples is large. Seasonal variation in food supply, geographic and climatic differences, and ethnicity may affect the short term food supply and thus influence body weight; sampling variation is an additional factor.

In a comparison of mean heights, weights and estimated BMI of 10 year old South African boys by ethnicity, all means are < 50th percentile of the NCHS reference. Boys of European ancestry are the tallest and heaviest, and have the highest BMI. "Colored" boys have the shortest mean height and lowest weight, and smallest BMI.

Nutrition and Infection

People in developing countries are exposed to greater infectious disease loads than people in developed nations, and there is significant interaction between undernutrition and infectious disease. Both undernutrition and infection are related to poverty, ignorance, and absence of public services (Martorell, 1982). Poverty and low income determine the quantity and quality of food available and the preventative measures adopted by families. Martorell (1982) also lists the lack of shoes, inadequate shelter and housing, and limited facilities and supplies for personal hygiene as important corollaries of poverty. Landlessness, poverty, food insecurity, high birth rates, lack of political commitment, migrant labor, limited breastfeeding, poor maternal nutrition education, absence of a national nutrition policy, and absence of trained health personnel are additional contributing factors to the high prevalence of PEM in South Africa (Fincham et al., 1996).

Some microorganisms, such as malaria and intestinal worms, utilize significant amounts of nutrients for their own growth, reproduction and maintenance, reducing the availability of nutrients to the host (Martorell, 1982; Stephenson et al., 1989, 1991). Poor nutritional status may possibly impair the body's defense against disease, and children who fail to thrive often suffer from recurring infections (Suskind, 1977). The impaired resistance may increase susceptibility to infection and create a cycle of repeated infection and undernutrition (Mata, 1972). The interruption of the infection-undernutrition cycle requires full immunization and aggressive work-up and treatment of the suspected infection in addition to improved nutrition (Frank and Zeisel, 1988). Estimates of the effects of infection and parasitic infestation on growth stunting, based on height-for-age, suggest that one-third of total linear growth failure can be ascribed to infection and diarrheal diseases (Allen, 1994).

Children in developing countries are exposed to large parasitic infestation loads, which are often endemic and asymptotic. An estimated 900 to 1,300 million people in the world are infected with at least one of the geohelminths, which includes hookworms, whipworms and roundworms (Adams et al., 1994).

Monitoring infections and infestations is largely a clinical process and requires sterile refrigeration of samples, specialized personnel, equipment, supplies and time, but incidence and prevalence data for infection and infestation, provide an indication of the relative impact of health problems in the area (Martorell, 1982). Clinical data, however, may reflect a sampling bias, and may not reflect the incidence and prevalence in the community as a whole. Individuals who go to traditional healers, or use home remedies, or over the counter drugs are not included. Furthermore, the incidence of infestations and infections are so high in some communities that they are no longer identified as problematic and go unnoticed, and certain diseases may be classified as less of a problem in some communities despite the endemic infection rates (Schutte, 1985; Martorell, 1982).

The prevalence of intestinal parasites in South Africa is high, and infection rates remain high despite municipal services to minimize the risk of infections by geohelmints (Fincham, 1996). A large part of South Africa has high rates of endemic waterborne diseases, which are particularly high in the Umgeni and Umsinduzi river catchment areas (Appleton and Bailey, 1990). Estimates of the prevalence of Cryptosporidium infection range between 9% (Moodley et al., 1991) and 18.4% (Berkowitz et al., 1989), while estimates of the prevalence of helminth infestation in South African children vary between 1.5% and 96% (Burger, 1968; Van Niekerk et al., 1979; Freeman and Grunewald, 1980; Schutte et al., 1981) depending on the age, ethnic group and geographic area studied. Gear and Pitchford (1985) estimate that approximately 2 million (5.3%) of all South Africans are infected with Schistosoma. However, the majority of the infected people are asymptotic, since they come from areas where schistosomiasis is endemic. It is estimated that 8% of rural Africans are infected with the tapeworm Taenia solium (Schutte, 1985), with prevalence as high as 20% in some areas (Heinz and McNab, 1965). Further, amoebiasis accounts for thousands of deaths annually, while malaria is endemic in many populations of South Africa (Schutte, 1985; Sharp et al., 1988).

Millar et al. (1989) identified Ascaris lumbricoides, Trichuris trichiura, Giardia lamblia, Enterobius vermicularis and Salmonella in a random sample of patients at a hospital in Cape Town. Of the 101 children sampled, 45.5% (46) were infested with parasites (Table 7). The authors estimated that at least one-half of the children in Cape Town may be at risk of complications from intestinal parasitic infestations.

Table 7. Parasitic infestation rates of hospitalized children in Cape Town.[a]

Parasite	Number	Percent of total (%)
Ascaris lumbricoides	8	17.4
Trichuris trichiura	8	17.4
Ascaris lumbricoides + Trichuris trichiura	20	43.5
Giardia lamblia	5	10.9
Giardia lamblia + Ttrichuris trichiura	3	6.5
Enterobius vermicularis	1	2.2
Salmonella	1	2.2

[a] Adapted from Millar et al. (1989)

Rates of parasitic infections in South African populations are high. A prevalence of 98% for Trichuris and 40% for Ascaris was noted in a West Coast South African community, which had purified drinking water supplied to all homes, flush toilets in 98% of the homes, a modern sewage disposal plant and regular garbage collection, free antihelmintic treatment at the community clinic, and electricity in 85% of the homes (Fincham et al., 1996). The high rates of infection were also evident in the prevalence of Schistosomiasis eggs in urine samples of South African canoeists (Appleton and Bailey, 1990). During 1988 and 1989, 70.7 % and 48.7% of canoeists, respectively, were diagnosed positive for schistosomiasis.

Despite the high prevalence of Schistosoma haemotobium, schistosomiasis is not considered as a significant cause of death in South Africa and is given low priority in terms of public health. Malarial infection, on the other hand, is not as high as schistosomiasis or geohelminth infections, but is the parasitic disease that is given the highest priority in South Africa (Schutte, 1985). Few studies (Connolly and Kvalsig, 1993; Fincham et al., 1996) have addressed the relationship between parasitic infection and the nutritional status in South Africa.

Connolly and Kvalsig (1993) found that 55.5% of children with trichuris and/or lumbricoides infections had height-for-age z-scores ≤ -1 compared to 19.7% of children without parasitic infection. Only 33% of children with parasitic infections had height-for-age z-scores $\geq +0.5$ compared to 52.5% of children who were not infected. The results suggest that a greater percentage of children with parasitic infections were stunted compared to those without infections. On the other hand, Stephenson et al. (1991) reported significant gains in both mass and stature in severely infected Kenyan boys four months after receiving a single dose antihelminthic treatment. However, in a subsequent study, treatment for intestinal parasites increased weight gain but did not improve linear growth of Kenyan school children (Stephenson et al., 1993).

Ghesquiere and Eeckels (1984) noted SES and ethnic variation in the prevalence of parasitic infestations in elementary school boys (6-13 years of age) from Kinshasa, Zaire (Table 8). Lower SES African boys had a higher prevalence of infestation, with 97% of the sample. In a series of studies on the effects of treatment of helminth infections on growth, nutrition and physical activity of Kenyan elementary school children, Stephenson et al. (1989, 1991, 1993) found that physical fitness, food intake and appetite of children improved following treatment for helminth infections compared to a control sample. The physical fitness of elementary school boys with hookworm, Trichuris trichiura and Ascaris lumbricoides who were treated with albendazole was assessed. The Harvard step test, heart rate, and heart rates at 1, 2, 3 and 4 minutes after the step test was measured at baseline and four months after a single dose of albendazole (Stephenson et al., 1991). Boys who received the antihelmentic treatment showed significantly better performances on the step test, while the placebo group showed no changes.

Table 8. Prevalence of infestations in school boys in Kinshasa.[a]

	African: Lower SES (Shanty Town)	African: Upper SES (Private School)	European: Upper SES
Abdominal distases	72.0%	0.0%	0.0%
Malaria	45.0%	1.5%	0.4%
Intestinal parasites	97.0%	63.0%	20.0%

[a] Adapted from Ghesquire and Eeckels (1984).

Data on physical activity and parasitic infections are mixed. Kvalsvig (1981) found an inverse relationship between the severity of parasitic infection and physical activity, with lower levels of physical activity in severely infested children. On the other hand, Walker et al. (1972) found that the running performance of 14 year old African boys (South Africa) with Schistosoma haemotobium infections was similar to that of uninfected African boys from the same areas. Kvalsvig et al. (1991) caution that some of the discrepancies in the literature on physical activity and parasitic infestation may be due to *a priori* differences in the groups. More active children have greater exposure to parasitic agents since they engage in play for longer periods of time increasing the risk of exposure to the parasite. On the other hand, severely malnourished or severely infected children are less active.

Catch-up growth

SES, ethnicity, and nutritional status affect the growth of children. This raises the question: Does the trend towards growth stunting follow an invariant negative path?

Martorell and coworkers (1990) posit that there is a limited ability for the chronically malnourished child to catch-up, since the stunting in height appears to be much greater than the delay in the appearance of the number of ossification centers in rural Guatemalan children. Observing a relationship between height at age 3 and final adult height, the authors concluded that stunting is a condition that results from events in early childhood and persisted with no catch-up growth in childhood or adolescence (Martorell et al., 1990). These findings are consistent with studies in South Africa (Chaning-Pearce and Solomon, 1986) and India (Satyanarayana et al., 1989) .

There is evidence to indicate that the efficacy of nutritional supplementation may decrease after the first 3 years of life (Satyanarayana et al., 1989; Martorell et al., 1990; Martorell, 1993; Perez-Escamilla and Pollitt, 1995). It has also been argued that providing nutritional interventions after the first three years of life has little or no potential to enhance physical growth (Yarbrough et al., 1975; Gillespie and Mason, 1991). On the other hand, some evidence indicates that enhancing nutritional status after three years of age may induce positive changes in stature (Martorell, 1993; Lampl et al., 1978), stature and mass (McKay et al., 1978), and weight-for-age and height-for-age (Stephenson et al., 1993). Data from the INCAP study in Gautemala indicated that the greatest growth stunting occurred during the first 3 years of life. This was also the period during which the greatest responses to the nutritional interventions were most likely to occur (Rivera et al., 1995). Thus, the size of the growth response to supplementation introduced after, compared to before, 3 years of age, was smaller.

A major reason for the disparity may be the period of time over which the follow up was conducted. In the initial Guatemalan study, subjects were followed for the first 7 years of life. Although children from the high protein-energy (Atole) villages were taller and heavier at three years of age compared to the energy only (Fresco) villages, there was little or no observable difference in the growth between the groups from 3 to 7 years of age (Martorell, 1990). When the same subjects were followed in late adolescence and adulthood (11 to 26 years of age), significantly greater stature, body mass and FFM were observed in the both the Atole and Fresco groups compared to nonsupplemented individuals from the same population (Rivera et al., 1995). At the follow-up, subjects from the Atole villages were taller and had greater estimated FFM than subjects from the energy only villages. The statistically significant differences in height and estimated FFM, equivalent to a positive shift of 0.5 SD, were not statistically significant when adjusted for height at age three.

Interventions introduced prenatally and during the first three years of life in rural Guatemala continued to produce benefits in growth years after the termination of the intervention (Rivera et al., 1995). Additionally, a 0.7 SD positive shift in $\dot{V}O_{2\,max}$, both absolute and per unit mass, was reported (Haas et al., 1995) and the differences in $\dot{V}O_{2\,max}$ (absolute and per unit mass) could not be explained by the differences in estimated FFM.

There was a statistically significant positive difference of 0.6 SD in the intellectual performance of the high protein-energy compared to the energy group (Pollitt et al., 1993). Subjects who received the high protein-energy supplementation during gestation and for the first 2 years of life also had a higher score in intellectual performance as adolescents (13-19 years of age) than those who began supplementation later in life. There also was a strong indication that the effects in adolescence were found only in cohorts exposed to supplementation during pregnancy and the first 2 years of life.

Pèrez-Escamila and Pollitt (1995) noted that gains in stature and mass associated with nutritional supplementation of Colombian children were in proportion to the duration of supplementation, regardless of the age (38, 42, 59, or 75 months of age) at which the nutritional intervention was introduced. Unlike the results for Guatemalan children (Rivera et al., 1995), the sample of Colombian children (Pèrez-Escamila and Pollitt, 1995) did not continue to demonstrate gains in height and weight after the cessation of supplementation. The Colombian subjects, however, were not followed into adolescence and adulthood.

Satyanarayana et al. (1989) found that adolescent boys who were severely malnourished at 5 years of age reached puberty later, had a significantly lower growth rate, a longer period of adolescent growth, and similar adolescent gain in stature to a British comparison group. The results suggest that undernutrition during childhood did not add to height deficits during puberty in this sample of Indian children. Cameron and Kgamphe (1993) found similar delays in the onset of and a prolongation of puberty in rural African populations in South Africa.

It is posited that preschool growth is largely determined by environmental factors such as nutritional status, SES and disease. Undernourished populations tend to have depressed preadolescent growth which accumulates throughout childhood, but the majority of the variation is established before six years of age. Although, adolescent growth is largely controlled by separate genetic factors (Tanner, 1962), negative environmental stresses in childhood may result in later puberty, and slower and longer adolescent growth (Chaning-Pearce and Solomon, 1986, 1987; Cameron et al., 1990). 'Colored' South African males and females who were treated for kwashiokor between the ages of 5 months, and 4 years and 4 months had delayed sexual maturation (Cameron et al., 1988; 1990). Additionally, lower SES Africans have a longer pubertal growth in stature and mass compared to Europeans (Chaning-Pearce and Solomon, 1986), and also have a later onset and prolonged duration of pubertal growth (Chaning-Pearce and Solomon, 1987). Low growth velocities during childhood result in mean heights and weights that are < 5th centile by the beginning of the adolescent growth spurt for approximately 50% of South African children (de Villiers, 1987; Cameron et al., 1988; Smit, 1969).

Summary

There is a strong association among ethnicity (race), SES and growth status in South Africa. Urban-rural status is also associated with SES and affects growth status.

The available literature indicates that rural African populations are lighter and have a lower BMI than urban African populations. Both urban African and Indian populations are shorter and lighter than European South Africans. The data for Indians, however, are limited. Variations in growth may be affected by nutritional status and infectious diseases, and repeated bouts of infectious diseases and may contribute to growth stunting.

Addressing the growth of any population in South Africa requires addressing the complex interrelationships among ethnicity, SES and nutritional status. Nutritional status differences have to be accounted for independently of the effects of ethnicity (race) and SES to partition the effects of each of these dynamic variables.

Physical fitness

The relationship between habitual physical activity and physical fitness of the child and adolescent is of relatively recent interest (Mirwald and Bailey, 1986; Pate et al., 1990; Baranowski et al., 1992; Shephard, 1992; Malina, 1995). Most of this interest was spurred by the Healthy People 2000 guidelines, which implied that many United States children and youth were physically unfit or insufficiently active and were at increased risk for cardiovascular disease later in life (Malina, 1995). This formed the impetus for health-related physical fitness which focused on developing physiological fitness to prevent premature morbidity and/or mortality due to a sedentary life style. The emphasis was largely on developing the fitness of youth for potential health benefits in adulthood (Malina, 1995).

Spurr (1983) estimates that only 9% of the variance in $\dot{V}O_{2\,max}$ is related to physical activity. However, there is a positive association between higher fitness and higher general activity. Fourth grade American children (mean age of 10.5 years) with higher general physical activity levels have higher physical fitness (Simons-Morton et al., 1990). Similar results are reported for a small sample (15 boys and 10 girls) of 6th grade (mean age 12.3 years) rural German children (Schmucker et al., 1984). There were significant moderate to low correlations between habitual physical activity and strength (r=0.42), aerobic capacity (r=0.67), basic skills (r=0.55), motor coordination (r=0.48) and motor communication (r=0.34) for the combined sample of males and females.

Motor performance is related to body size in both well-nourished and undernourished children (Malina, 1975, 1994; Malina and Little, 1985; Malina et al., 1987). Mild-to-moderate undernutrition is also characterized by reduced fat-free mass and fat mass (Barac-Nieto et al., 1978; Satyanarayana et al., 1979; Desai et al., 1984; Malina et al., 1991), reduced bone density and metacarpal cortical thickness (Himes, 1978), and reduced strength, motor performance and aerobic fitness (Barac-Nieto et al., 1978; Spurr et al., 1983a, 1983b, 1991; Malina and Bushang, 1985).

There is reasonable consensus that undernourished children score lower on tests of performance- and health-related fitness, including speed, power, strength, and endurance compared to nutritionally normal children (Sloan, 1966a; Sloan and Hansen, 1969; Ghesquiere and Eeckels, 1984; Malina, 1984; Malina and Buschang, 1985; Malina et al., 1991; Goslin and Burden, 1986; Benefice, 1993). Motor skill acquisition and performance is influenced by cultural and environmental exposure to the skill, and the growth and maturational status of the individual, among other factors. There is, however, considerable variation in the normal range of motor skill attainment and the rate of development is influenced by a variety of environmental factors (Branta et al., 1984).

Physical fitness is separated into health-related and performance-related fitness. Performance-related fitness is an indication of the attained levels of motor performance. Static strength (grip strength), agility (shuttle runs), running speed (dash) and explosive power (standing long jump) are components of performance-related fitness. Current emphasis is more on health-related fitness, which is a state characterized by an ability to perform daily activities with vigor and demonstrate traits and capacities that are associated with low risk of premature development of the hypokinetic diseases (Pate, 1988). It is operationalized as cardiorespiratory endurance (9 minute run), musculoskeletal function (sit and reach, push-ups and sit-ups), and body composition (subcutaneous fatness) (AAPHERD, 1984).

The development of behavioral competence in motor tasks is a major developmental task of childhood and youth. Fundamental motor patterns are established during early childhood, conditioned by the interaction of genotypic and environmental factors, and influenced by the opportunity to practice the new skills (Malina, 1992). Motor skill implies both economy and precision, and is related to age, body size and composition, opportunity for practice, and motivation, among other factors (Malina et al., 1987).

Eight studies of the physical performance and/or fitness of South African children and adolescents, which spanned approximately 50 years from 1942 to 1992, a period over which considerable sociopolitical restructuring has occurred in South Africa, are reviewed. Two of the studies from the 1940s provide a reference for changes in performance status over the past 50 years, while three studies are from the 1960s and another three are from the 1980s. Subjects are separated according to the prevalent racial groups of African, "Colored", Indian and European, but Indians are included in "Colored" samples in some studies.

Most of the South African literature focuses on the performance-related physical fitness of pubertal children, with a limited data for prepubertal children. The samples are drawn from high school populations, which are not necessarily representative of the general population. Until 1992 education was free and compulsory only for Europeans, and African education received the least federal funding (Table 1). The cost of education often limited school attendance for African children. Education also became progressively selective with each successive year of formal schooling. Consequently, high school attendance was limited to individuals from families of higher SES. Additionally, most African and "Colored" school students worked to subsidize their schooling, dropping out of school for a year or two as dictated by the economic situation of the family.

The studies of the performance-related physical fitness of youth of different racial groups point to higher scores for European post-pubertal males compared to African, "Colored" and Indian youth. There are also differences in the performances of prepubertal, circumpubertal and pubertal males relative to body size and ethnicity. Early studies (Culver et al., 1942; Botha et al., 1945) indicated that, despite the higher incidence of undernutrition and parasitic infestations, African boys classified as prepubertal had superior performances on the 100-yard dash and 600-yard run compared to European, "Colored" and Indian prepubertal boys. On the other hand, prepubertal European boys had superior performances on the shot put compared to prepubertal African, "Colored" and Indian boys. Botha et al. (1945) attributed the superior shot put performance of European boys to their larger body size and better neuromuscular development. The criteria for the classification of pubertal status, however, was not specified.

In early studies, "circumpubertal" (immediately before and after puberty) European boys had superior running performances on the 100-yard dash and 600-yard run compared to African boys (Culver et al., 1942). Sloan (1966a, 1966b) found a positive association between the performances of pubescent European boys and estimated muscle mass. This correlation probably reflects the larger body size and advanced maturity status of European compared to African, "Colored" and Indian males. On the other hand, the performances of prepubertal boys on the 10-yard dash and 600-yard run were negatively correlated with body size (Culver et al, 1942; Botha et al., 1945). The results suggest that while strength appears to be a significant determinant of performance on the 100-yard dash and 600-yard run during puberty, other factors such as running economy and skill level may have determined preadolescent performances.

Greater body size is associated with better physical performances in some tasks. Several studies (Sloan, 1966a, 1966b; Goslin and Burden, 1986) indicated superior performances for European pubertal adolescents, who were consistently taller and heavier than boys from other racial groups. This raised the question: Was the superior post-pubertal performance of European males related to their greater body size? In a sample of 12-18 year old males, Sloan (1966a) observed that European males were taller, heavier and demonstrated superior performances on sit-ups, the shuttle run, standing long jump, 50-yard dash, softball throw for distance, and 600 yard run-walk (AAPHER fitness test) compared to African and "Colored" (which included Indian) males of the same age (Table 9). "Colored" males performed better than African males on most tests, despite a lower body weight. African boys had the poorest performances on all items except for the softball throw for distance. Thus, differences in performance appear to be affected by factors other than body size. Body composition, skill and practice were not considered as possible sources of variation in performance, in these early studies

Fitness indices, calculated from age-specific T-scores for the 6 items of the AAPHER tests of European, African and "Colored" males were compared by Sloan and Hansen (1969). European males had a superior Fitness Index compared to African and "Colored" boys and the performance-related fitness did not appear to be related to body size. Statistically controlling for the effects of stature and body mass had no effect on the Fitness Index. The relationship between body size and fitness, however, appeared to differ among the racial groups. When the effect of weight was controlled, heavier 13 year old European males had a higher Fitness Index compared to lighter European males,

Table 9. Comparison of the mean body size and performance-related physical fitness of adolescent South African males 12 to 18 years of age by age and race.[a]

Age in Years	12	14	16	18
Stature (cm)				
European	152	164	177	183
"Colored"	144	156	164	170
African		154	162	172
Weight (kg)				
European	41	51	63	67
"Colored"	36	43	52	58
African		44	56	60
Sit-ups (# to exhaustion)				
European	64	80	81	88
"Colored"	47	47	50.5	49
African		28	34	30
Shuttle run (sec)				
European	10.8	10.2	9.9	9.5
"Colored"	10.9	10.7	10.3	10.1
African		10.9	10.3	10.2
Standing broad jump (cm)				
European	177	198	222	231
"Colored"	171	183	204	204
African		171	183	198
50 yard dash (sec)				
European	7.8	7.1	6.6	5.9
"Colored"	7.9	7.4	7.2	7.0
African		8.0	7.5	7.8
Softball throw (m)				
European	12.7	15.8	20.2	23.9
"Colored"	12.2	14.6	16.8	17.3
African		14.9	17.3	19.2
600-yard run-walk (min:sec)				
European	2:01	1:53	1:45	1:40
"Colored"	2:05	1:55	1:50	1:46
African		2:40	3:06	2:30

[a] Adapted from Sloan (1966a). Items are from the AAPHERD fitness test.

indicating an advantage of weight. On the other hand, heavier 13 year old "Colored" boys had a lower Fitness Index than lighter "Colored" boys, indicating a disadvantage of weight. Body composition and maturity status potentially affect the Fitness Index. Taller and heavier European males were likely advanced in maturity status with a higher percentage of muscle tissue compared to "Colored" and lighter European boys, which perhaps contributed to the performance advantage of their higher body mass. Additionally, the apparent race difference in the relationship between body size and fitness could be due to the use of an index. The Fitness Index is a composite score of test items and does not reflect individual variation on specific test items. Thus, strengths and weaknesses on individual test items are masked by the Fitness Index.

SES, training, experience and nutritional status are some of the factors that may affect the performance-related fitness of South African boys. European schools had gymnasiums and trained physical education teachers, whereas Black schools had neither. Additionally, European schools had compulsory participation in one summer and one winter sport that were practiced for 3 to 4 afternoons per week (Sloan and Hansen, 1969). Black schools had no formal physical education curricula and extramural sport was offered once a week. The consistently poorer performances of African, "Colored" and Indian, compared to European, subjects may thus be related to differences in habitual physical activity and access to the opportunity for instruction and practice.

While skill and training appear to be important determinants of performance in nutritionally normal subjects, evidence indicates that strength and performance are related to body size in undernourished populations. The absolute performances of undernourished children are generally lower than those of well nourished children (Culver et al., 1942; Botha et al., 1945; Ghesquiere and Eeckels, 1984; Malina and Little, 1985; Malina et al., 1987; Benefice, 1992; Benefice et al., 1996). However, many of the observed differences are decreased or are reversed when performances are expressed per unit body mass. This suggests that the poorer performances of undernourished youth are more related to reduced body size rather than to differences in metabolic processes.

Absolute grip strength is lower in undernourished children, but is similar for nutritionally normal and undernourished children per unit body mass (Malina et al., 1987). The absolute strength scores of European males in South Africa are comparable to American children of the same age (Goslin and Burden, 1986). African and "Colored" children, on the other hand, have lower absolute strength compared to American children on the same age. But, when expressed relative to body mass, the mean grip strength of African and "Colored" boys is greater than that of European boys (Table 10).

The dash and long jump performances of moderately undernourished Zapotec Indian (Mexico) children (6-15 years old) were proportional to smaller body size in younger but not in older boys (Malina and Buschang, 1985). When performances of Kinshasa (Zaire) elementary school children (6-13 years of age) were expressed per unit body size, boys from a lower SES group performed slightly, but consistently, better on the medicine ball throw, hand grip, vertical jump, and 50 m dash (Ghesquière and Eeckels, 1984).

Despite lower body mass and estimated FFM of undernourished children, they have higher absolute scores on some tasks (Malina and Buschang, 1985; Ghesquière and

Table 10. Comparison of the physical fitness (means) of adolescent South African boys by race.[a]

	European	"Colored"	African
Age (years)	16.8	18.1	18.5
Activity level	10.0	9.0	9.5
Mass (kg)	68.0	59.0	61.0
Stature (cm)	177.0	169.5	172.0
Grip (kg)	89.0	81.0	90.0
Grip (kg/kg body mass)	1.3	1.4	1.5
Power (watts)[b]	1116.0	895.0	725.0
Power (watts/kg body mass)[b]	16.4	15.2	11.9
Medicine ball (4.5kg) push (cm)	210.0	185.0	155.0
Standing long jump (cm)	216.0	210.0	190.0
Sit-ups (#/min)	45	38	30
Half hold push-up (sec)	49	68	52
Sit, reach and hold (cm)	31.5	35.0	35.5
Shuttle run (sec)	12.0	11.0	12.2
Estimated body fat (%)	12.0	11.0	11.0
Predicted $\dot{V}O_{2\,max}$ ($ml.kg^{-1}.min^{-1}$)	61.0	52.0	49.0

[a] Adapted from Goslin and Burden (1986)
[b] Heart rate not indicated

Eeckels, 1984). Performances on the standing long jump appeared to be independent of body size in undernourished adolescents. Superior standing long jump performances were reported for adolescent "Colored" girls despite their smaller body size (Goslin and Burden, 1986). Slightly better throwing performances were observed in marginally undernourished Zapotec Indian boys in Mexico (Malina et al., 1987) and African boys (Sloan, 1966a). Malina et al. (1987) suggest that the higher performance scores may have been related to specific cultural practices. Goslin and Burden (1986) also suggest that ethnic variation in level of skill may be due to individual cultural experiences of children.

Time related trends in physical fitness, based on a comparison of studies in 1966 and 1985 indicated no major differences between the stature of 16 year old European and 18 year old African and "Colored" males (Table 11). European boys were heavier in

1986 by 5 kg, but "Colored" and African males had similar body weights in 1966 and 1985. Performance of African, "Colored" and European boys on a shuttle run and the standing long jump were lower in 1986. Shuttle-run performances declined by 17.5% and 16.4% for European and African males, respectively, in 1986. "Colored" males had the best shuttle-run performances in 1986, despite the 8% decline in performance from 1966. European males had greater explosive strength on the standing long jump in both 1966 and 1986, compared to African and "Colored" boys. "Colored" males performed

Table 11. Comparison of age, body size and physical performances (means) of adolescent European, 'Colored' and African South African males between 1966 and 1985.[a]

	Sloan (1966)	Goslin and Burden (1986)
Age (years)		
European	16.5	16.8
"Colored"	18.5	18.1
African	18.5	18.5
Stature (cm)		
European	177	177
"Colored"	170	169
African	172	172
Weight (kg)		
European	63	68
"Colored"	58	59
African	60	61
Shuttle run (sec)		
European	9.9	12.0
"Colored"	10.1	11.0
African	10.2	12.2
Standing long jump (cm)		
European	222	216
"Colored"	204	210
African	198	190

[a]Time for the 50 meter dash

better than African males on the standing long jump, both in 1966 and 1986. However, the difference between the performance of European and "Colored" males on the standing long jump was smaller in 1986 compared to 1966.

The lower mean performances in 1986 could be related to lifestyle changes which coincided with the introduction of television in 1974. The reduced physical fitness and physical activity of American children are often attributed to increased television viewing (Dietz and Gortmaker, 1985). This assertion assumes that activity and performance are themselves related. While there is no conclusive evidence to support these contentions, the initial introduction of television into a society could have had some effect on overall activity levels, but does not necessarily translate into decrements in physical fitness. Additionally, South African European boys were heavier in the 1986 study, and the increasing adiposity of American children and youth has been attributed to television viewing (Dietz and Gortmaker, 1985). However, cohort differences between 1966 and 1986 possibly contribute to the variation in performance.

Some evidence indicates a correlation between high levels of habitual physical activity and submaximal endurance capacity. Participation in physical activity in non-summer months, involvement in a varied physical education curriculum, weekly activity time in physical education, and involvement in lifetime physical education were some of the factors that had a significant relationship with the performance on the 1 mile walk/run of 10 to 12 year old children from the NCYFS (Dotson and Ross, 1985). No specific correlations were given, however. Students scoring below the average range also reported participation in fewer high intensity physical activities compared to students who performed in the optimal range.

Studies on the relationship among ethnicity, performance-related fitness, SES, and nutritional status of South Africans are not conclusive (Sloan, 1966a, 1966b; Sloan and Hansen, 1969; Goslin and Burden, 1987; Badenhorst et al., 1992). Ghesquiere and Eeckels (1984), however, found a strong correlation among SES, ethnicity and performance of boys from Zaire. Children of European ancestry were of higher SES, taller and heavier, and had higher absolute performances compared to boys of African ancestry (Ghesquiere and Eeckels, 1984). Similarly, on average, African boys (South Africa) were of lower SES, shorter and lighter, and had lower absolute performance scores on the sit-ups, shuttle run, standing long jump, 50-yard dash (Sloan, 1966a), medicine ball push and tests of absolute and relative power compared to European boys (Goslin and Burden, 1986). The difference in physical fitness are confounded by the strong race by SES interaction, which in turn, affects nutritional status and could be due to an SES by nutritional status interaction as opposed to race.

Work capacity and $\dot{V}O_{2\,max}$

Work capacity and maximal oxygen capacity ($\dot{V}O_{2\,max}$) are affected by body size, age, maturity status, body composition, training and nutritional status, among other factors (Krahenbuhl et al., 1985). In an examination of the $\dot{V}O_{2\,max}$ of nutritionally normal White, Mestizo and Black Colombian boys 6-16 years of age, no significant age, race, or SES differences in absolute $\dot{V}O_{2\,max}$ were observed (Spurr et al., 1983b).

However, low weight-for-age and low weight-for-height children had markedly lower absolute $\dot{V}O_{2\,max}$ ($l.min^{-1}$) compared to nutritionally normal children. When $\dot{V}O_{2\,max}$ was adjusted for body size ($ml.kg^{-1}.min^{-1}$), marginally malnourished children had equal or higher relative $\dot{V}O_{2\,max}$ (Table 12). At the same absolute workload, undernourished children performed at a relatively higher workload (51 to 54% of $\dot{V}O_{2\,max}$) compared to normally nourished (41% of $\dot{V}O_{2\,max}$) children (Spurr, 1983; Spurr et al., 1983b).

Table 12. Absolute and relative $\dot{V}O_{2\,max}$ of normally nourished, low weight-for-age and low-weight-for-height 6 to 16 year old Colombian boys.[a]

Oxygen consumption	Control	Low W-A[b]	Low W-H[c]
Weight for age	> 95%	< 95%	< 95%
Weight for height	> 95%	> 95%	< 95%
$\dot{V}O_{2\,max}$ ($l.min^{-1}$)	1.8	1.53	1.48
$\dot{V}O_{2\,max}$ as a % of control group ($l.min^{-1}$)		85%	82%
$\dot{V}O_{2\,max}$ ($ml.kg^{-1}.min^{-1}$)	52	53.89	55.43
$\dot{V}O_{2\,max}$ as a % of control group ($ml.kg^{-1}.min^{-1}$)		104%	107%

[a] Adapted from Spurr et al. (1983b)
[b] W-A = Weight-for-age
[c] W-H = Weight-for-height

It is generally assumed that functional capacity is impaired by marginal undernutrition. The relationship between nutritional status and physical working capacity (PWC_{170}) of 12-year old migrant and well-to-do boys from Ribeirao Preto, Sao Paulo (Brazil) was examined by Desai et al. (1984). The migrant boys had a mean nutrient intake that was 62.5% of the FAO/WHO recommended daily intake and 85% of the control group of well-to-do boys, respectively. Although the well-to-do controls had caloric intakes that were lower than recommended daily allowances, their protein intake was within the normal range. Baseline heart rates at rest were the same for the two groups. Compared to the well-to-do controls, the undernourished boys had higher mean heart rates at each submaximal workload on the bicycle ergometer which remained significantly higher during the first two minutes of recovery, higher oxygen consumption per unit body weight, and higher levels of muscle lactate (Table 13). Overall, undernourished boys worked at a higher relative workload for the same absolute workload compared to well nourished age mates, and had greater muscular stress than the well-to-do controls.

Table 13. Oxygen consumption of migrant and well-to-do 12 year old Brazilian boys.[a]

Oxygen consumption	Workload (Watts)	Well-to-do	Migrant
$\dot{V}O_{2\,max}$ ($ml.min^{-1}$)	0	209	190
$\dot{V}O_{2\,max}$ ($ml.min^{-1}$) % of w-t-d[b]			91%
$\dot{V}O_{2\,max}$ ($ml.kg^{-1}.min^{-1}$)		4.8	5.6
$\dot{V}O_{2\,max}$ ($ml.kg^{-1}.min^{-1}$) % of w-t-d			117%
$\dot{V}O_{2\,max}$ ($ml.min^{-1}$)	75	1011	987
$\dot{V}O_{2\,max}$ ($ml.min^{-1}$) % of w-t-d			98%
$\dot{V}O_{2\,max}$ ($ml.kg^{-1}.min^{-1}$)		23.1	29.0
$\dot{V}O_{2\,max}$ ($ml.kg^{-1}.min^{-1}$) % of w-t-d			126%

[a] Adapted from Desai et al. (1984)
[b] w-t-d= well- to do

Stature and mass are significant determinants of the physical work capacity of (PWC) and the relationship is more marked for undernourished individuals. The PWC of marginally undernourished Brazilian boys was 71% that of a same-age control group from the same town, but increased to 91% when expressed per unit mass (Desai et al., 1984). Body mass alone, however, accounted for only 16% of the variation in work capacity of marginally malnourished males, but when stature was added to mass, 57% of the variance was explained. On the other hand, 64% of the variance in physical work capacity of severely malnourished adolescent Indian boys, classified into three nutritional groups based on stature at 5 years of age, was explained by mass at the time of testing (Satyanarayana et al., 1979), which indicated a greater influence of mass on work capacity in severely malnourished subjects.

Undernourished rural African boys from Johannesburg, with an estimated mean daily nutrient consumption between 37-41% of the recommended daily allowances (Badenhorst et al., 1992), had significantly lower absolute and relative $\dot{V}O_{2\,max}$ (Table 14) compared to normally nourished boys from Canada (Mirwald and Bailey, 1986) and Colombia (Spurr et al., 1991). Despite undernutrition, this sample of boys was relatively taller than all other samples of South African boys. The disparity between growth and nutritional status of the rural African males may have been due to under-reporting of food intake on the 24-hour dietary recall, or seasonal variation in diets that were typical of rural populations, or perhaps the result of a very select sample.

Table 14. Absolute and relative $\dot{V}O_{2\,max}$ of boys with a mean age of 10.5 years.

	$\dot{V}O_{2\,max}$ (l.min^{-1})	$\dot{V}O_{2\,max}$ (ml.kg^{-1}.min^{-1})
South Africa (Badenhorst et al., 1992)	1.55	49.7
Saskatchewan, Canada (Mirwald and Bailey, 1986)	1.80	56.2
Argentina (Perez et al., 1991)		
Lower SES	1.13	36.2
Upper SES	1.50	43.0
Colombia (Spurr et al., 1991)		
Urban - normally nourished	1.66	53.6
Rural - normally nourished	1.62	52.3

It has been argued that walking and bicycling, which are used as a primary mode of transportation for African and "Colored" children and youth, should have a training effect on work capacity (Wyndham, 1963). Undernourished rural African boys walked or cycled between 5 to 15 km to and from school each day, but their $\dot{V}O_{2\,max}$ was considerably lower than nutritionally normal age mates (Badenhorst et al., 1992). Furthermore, $\dot{V}O_{2\,max}$ was consistently higher in European than in African adolescents (Goslin and Burden, 1986) and adults (Wyndham, 1963). The differences in $\dot{V}O_{2\,max}$ could be due to a training effect of higher intensity extramural activity as opposed to the lower intensity of walking and cycling which did not provide a significant training effect.

Physical fitness (1.6 km run/walk) and habitual physical activity had a low (R^2=0.21), but significant relationship in 8 to 9 year old children from the NCYFS II study (Pate et al., 1990). Some of the variation in physical fitness was accounted by the global rating of the child's activity level (11%), participation in vigorous community activity (5%), participation in physical education at school (2%) and involvement in private clubs/lessons and television viewing (1%). Habitual physical activity, regardless of mode, appears to have a relatively small positive effect on the performance on the one mile run/walk test. Schmucker (1984) reported a moderate correlation (r=0.67) between habitual physical activity and aerobic capacity for a combined sample of rural German boys and girls (mean 12.3 years of age). The 1.6 km run and $\dot{V}O_{2\,max}$ do not necessarily measure the same thing. Other factors that could explain the differences in between habitual physical activity and endurance performance possibly include lifestyle factors and sample size. The higher correlation between habitual physical activity and endurance performance in the latter study may be due to lifestyle differences. Children from rural Germany possibly engage in higher levels of habitual physical activity compared to children from the USA and this may possibly influence endurance performance. The German study has a small sample size (n=25) and possibly affects the association between habitual physical activity and endurance performance.

Satyanarayana et al. (1979) noted a moderate correlation (r=0.53) between habitual physical activity and physical work capacity (PWC_{170}) of chronically undernourished adolescent Indian males, even after controlling for the effects of body mass. Physical activity status was the single parameter that had a significant relationship to work capacity per unit body mass, and 10% of the variation in PWC_{170} could be explained by habitual physical activity. Satyanarayana et al. (1979) postulated that the differences in work capacity could be due to activity induced changes in the cardiovascular and neuromuscular system. On the other hand, nutritional status history - the duration and severity of undernutrition - could have predisposed the individual towards lower levels of habitual physical activity which, in turn, resulted in a lower submaximal work capacity.

Barac-Nieto et al. (1978) found a linear relationship between the degree of undernutrition and $\dot{V}O_{2\,max}$ of adult Colombian men. The more nutritionally compromised the individual, the lower the $\dot{V}O_{2\,max}$. This relationship did not change with adjustments for body mass, height, and estimated FFM, body cell mass, or muscle mass. This study did not take into account the potential self-selection of lower levels of habitual physical activity by adults with lower $\dot{V}O_{2\,max}$. Marginally undernourished individuals are able to perform the same low levels of work as normal individuals, but at a relatively higher level of energy expenditure (Spurr et al., 1977; Barac-Nieto et al., 1978; Satyanarayana et al., 1979; Desai et al., 1984). The energy consumption required to sustain a normal daily workload was estimated to be approximately 40% of $\dot{V}O_{2\,max}$. Spurr et al. (1983b) hypothesized that working at even 40% of $\dot{V}O_{2\,max}$, undernourished subjects would be less productive adults, on average. Energy deficiency related decreases in $\dot{V}O_{2\,max}$ may result in a lower ability to sustain a given absolute work load and in the time that a given relative effort could be sustained (Barac-Nieto et al., 1978).

Summary

Body size, SES, race and nutritional status appear to affect physical activity and fitness. SES, race and nutritional status are interrelated in most developing world populations. Thus, while SES, race and nutritional status differences in physical fitness and habitual physical activity have been observed in several populations, race-, SES- and nutritional status-specific differences are most likely confounded by each other. Some of the trends observed include lower scores on tests of speed, power, strength and endurance of undernourished compared to nutritionally normal children. Race differences in physical fitness and habitual physical activity are evident among children from South Africa and Zaire, but these were not systematically analyzed in a SES context.

In South Africa, African boys have poorer performances on performance-related fitness tests compared to European boys, except on the dash and distance run. Physical performance is related to body size, with greater size associated with better performances on some items. The apparent race differences in fitness may be due to interations of SES, race and growth status since European boys also have a larger body size and scored higher on fitness tests. Similar race, SES, nutritional status and growth interactions were found in Zaire. The relationships, however, are not clear. In South Africa, despite being lighter than African boys, Colored boys have better fitness scores than African boys

Skill training and the opportunity to practice are factors that influence performance on some fitness tests, and may be related to SES factors. In addition, lifestyle factors such as mode of transportation and habitual physical activity could contribute to differences in endurance and cardiorespiratory fitness. There is some evidence to support the contention that higher habitual physical activity results in higher submaximal endurance capacity. But, undernourished populations have a lower physical work capacity and work at a relatively higher workload for the same absolute load compared to nutritionally normal populations, which suggest that their work capacity may be compromised.

Differences in physical fitness and habitual physical activity need to be examined within the context of SES, race, current nutritional status, and nutritional history. The independent contributions of SES, race and nutritional status to specific fitness variables also need to be explored.

Habitual Physical Activity

Physical activity is a component of total energy expenditure, which also includes basal and resting metabolism, the thermic effect of food, and growth (Malina and

Bouchard, 1991). Physical activity is a culturally bound concept and varies with ethnic, cultural and SES conditions within the same society (Torun et al., 1996). There are marked differences in the amount of time that children spend in structured and spontaneous physical activities (Simons-Morton et al., 1990; Spurr and Reina, 1990). In both developed and developing countries, there are SES and urban-rural differences in activity participation.

SES differences in habitual physical activity are affected by interpersonal, physical and social environments, public policy and the interaction of these variables (McLeroy et al., 1988; Sallis et al., 1997; King et al., 1995). Environments rich in resources such as sidewalks, parks, exercise facilities and health clubs make it easier for people to be physically active (Sallis et al., 1997). Children in environments that have high rates of crime, poverty and crowding engage in higher levels of sedentary activity (Sallis et al., 1993; Goodway, 1994; Branta and Goodway, 1996). Goodway (1994) found that Flint inner city children in an environment with high crime, unemployment, small housing conditions, and poverty engaged in predominantly sedentary indoor activities and had little or no exposure to physical activity outside of school. Poor communities that have few resources are less able to provide recreation and activity resources than more affluent ones. Branta and Goodway (1996) concluded that streets and the playgrounds of poor at-risk communities are often not safe places in which to exercise or play.

The availability of open space also serves as a catalyst for habitual physical activity of higher intensities. Approximately 2% of the variation in mean daily total estimated energy expenditure (kcal/day) of 12 to 14 year old Taiwanese school boys was attributed to SES (Huang, 1994). On the other hand, the locality of the school - urban or rural - accounted for 6% of the difference in energy expenditure, with rural boys being more active than urban boys (Huang, 1994). Approximately 2% of the variation in estimated energy expenditure in MVPA (kcal/day) was explained by school differences. Additionally, urban-rural locality of schools explained 6%, 4% and 4% of variation in the mile run (time), sit-ups (per minute) and sit and reach (cm) tests, respectively.

In low SES urban and rural families, there is a heavy burden of participation in domestic chores and waged labor at an early age (Berg, 1973). Children from upper SES families, on the other hand, participate more often in structured extracurricular physical activities. In South Africa, European boys spend considerably more time in organized sport activities outside of school than African, "Colored", or Indian boys (Sloan, 1966a; Goslin and Burden, 1986).

Habitual physical activity has a significant cultural component and reflects the customs of the family and a society. In a study of 1,610 subjects from 375 Quebec families, Pérusse et al. (1989) estimated that genotype accounted for 29% of the transmissible variance in the estimated level of habitual physical activity. It was suggested that children could acquire the behaviors towards physical activity from his/her parents. Cultural transmission accounted for 12% of the transmissible variation in physical activity. Non-transmissible environmental factors, such as common environment and lifestyle, accounted for 71% and 88% of the phenotypic variation of the habitual physical activity and exercise participation, respectively.

Measuring and quantifying physical activity

Quantifying physical activity and exercise habits is difficult. The validation of methods of assessing physical activity is complicated by the fact that it is "impossible to obtain a 'gold standard'" (Blair, 1984; Baranowski et al., 1992). Physical activity is an observable phenomenon. Thus, the validation of methods of measuring and quantifying physical activity have traditionally been against observational data. Observation, however, is subjective and the reliability of observation needs further research (Baranowski et al., 1992).

The recall method is particularly easy and useful, but is limited to older children and adults. The recall method is also confined to assessing activity in the few days immediately preceding the recall (Blair, 1984). The use of short term recall reduces the amount of time available for memory decay, but there is no way to ensure that the week/period is representative of the physical activity of the individual (Washburn and Montoye, 1986). A combination of methods for the evaluation of physical activity is proposed by some since it provides the highest level of accuracy while maintaining practicality (Saris et al., 1980; Saris, 1986).

The activity of children has been estimated in numerous ways, including parental reports (Seliger et al., 1974), self-reports by children under the guidance of a teacher (Shephard et al., 1980), and reports by the teacher on the child that were completed at the end of each day (Saris et al., 1980), among others. One of the major problems of having a parent or teacher report on the activity of a child is that the parent or teacher is only aware of the activity that the child engages in while in the presence of the adult, or by what the child tells the adult. This potentially fails to account for a significant portion of activity that occurs in the non-observed time. The greatest advantage of the self-report is that it can be used easily with large numbers of subjects. However, the recall technique is not useful for children under 10 years of age (Bouchard et al., 1983; Baranowski et al., 1992).

Some of the problems with recall questionnaires include estimation of the duration and intensity of activity, selective recall, discrimination of activity intensity at high values, developmental appropriateness, and conversion of data (Baranowski et al., 1984, 1992). The ability of children to recall and report the intensity and duration of physical activity is limited, and is related to culture, education and age. Thus, young children are less reliable in recalling their activity accurately, and daily fluctuations in activity levels make recall more difficult (Baranowski et al., 1992). Further, chronological time is a culturally bound concept and is often a factor of education. In many developing countries children and adults do not own watches. Reporting the duration of an activity presupposes ownerships and/or frequent access to a clock, as well as a finely developed sense of chronological time.

Segmenting the day into functional components and having the child record aerobic activity within each component rather than the whole day increases the accuracy of self reports (Baranowski et al., 1984). Children in 3rd to 6th grades have difficulty making accurate minute-by-minute-time estimates, and in estimating the duration of an activity regardless of the response format used. Providing options for time estimation other than a statement of precise minutes of expired time enhances the accuracy of reporting.

Simons-Morton et al. (1990) observed that children consistently reported greater intensity and duration for moderate to vigorous physical activities (MPVA). There was a 86.3% agreement between the reported and observed number of MPVA that were ≥ 10 minutes. Similar overreporting of high levels of physical activity was noted by Baranowski et al. (1992), and may be a result of the limited ability of the children to recall, or the tendency to report the total amount of time that they were engaged in the activity, as opposed to the amount of time that they were truly active.

All types of recall are intrusive on the subject, but this is exacerbated when the subject is required to make a record of all activities. Recording of activities places a great burden for compliance with the measurement protocol on the individual and could result in noncompliance, or the effort required could cause him/her to change his/her normal activities (Blair, 1984). By focusing on the typical patterns or activity, there is a smaller burden on the subject to recall all miscellaneous activities. The activity pattern questionnaire is a less intrusive instrument since the subject is required to report only general or typical patterns of activity rather than to recall specific activities.

Physical activity reports are used to estimate the time and energy expenditure at different levels of activity, using standard conversion charts (Bouchard et al., 1983; FAO, 1985). However, the energy expenditure of children and adults are not the same. Children have a higher energy expenditure and oxygen cost during weight-bearing activities per unit body weight than adults, and the differences are greater at younger ages (Astrand, 1952; Bar-Or, 1983). Consequently, the use of standard conversion charts leads to an underestimation of energy expenditure in people under the age of 20 (Sallis et al., 1991).

Torun et al. (1983) estimated that the energy cost of basal metabolism was 38 $kcal.kg^{-1}.min^{-1}$ for children < 10 years compared to 18 $kcal.kg^{-1}.min^{-1}$ for adults. This increased to 44 $kcal.kg^{-1}.min^{-1}$ for children when lying down, compared to 20 $kcal.kg^{-1}.min^{-1}$ for adults. Furthermore, energy costs did not remain constant and the child-to-adult ratio of energy expenditure declined from 2.2:1 for lying down to 1.1:1 for walking up and down hill and climbing stairs (Torun et al., 1983). These estimates were based on the energy expenditure of subjects who had previously been undernourished but were currently well-nourished. Sallis et al. (1991), on the other hand, based estimated energy expenditure of children on an analysis of several studies. However, no information on the studies, nutritional status of subjects, or number of studies was cited. Sallis et al. (1991) estimated that there was a consistent 20% underestimation of energy expenditure for 10 year old children, with an age-adjusted energy cost ratio of 1.18 of standard adult values.

Habitual physical activity patterns of children

From middle childhood onwards, there is a greater development of proficiency in movement skills and the ability to participate in structured activities (Haubenstriker and Seefeldt, 1986). Running, walking fast, sports and games, and bicycling accounted for over 70% of the moderate to vigorous physical activities for a sample of third and fourth grade girls and boys from Texas (Simons-Morton et al., 1990). Similarly, the five top-ranked physical activities of Taiwanese boys (12-14 years of age) were basketball, bicycling, jogging, walking and running (Huang, 1994).

The intensity of participation in physical activity decreases with increasing age. In an examination of the activity patterns of 6 to 16 year undernourished and normally nourished Colombian children, no significant age effects in the 12 hour average heart rate frequency were observed, with children spending progressively more time at lower heart rates and less at higher rates in their daily activity as they grew older (Spurr and Reina, 1990). Between 7 to 10 hours a day were spent on workloads < 30% $\dot{V}O_{2\,max}$, approximately 1.5 - 4 hours a day were spent on activities that were between 30% to 50% $\dot{V}O_{2\,max}$, and on average, between 20 to 60 minutes a day were spent at levels >50% $\dot{V}O_{2\,max}$. The average 12 hour percentage $\dot{V}O_{2\,max}$ ranged from 20% to 30% of $\dot{V}O_{2\,max}$ and increased with age. Additionally, undernourished 6 to 8 year old boys worked at significantly lower values of percentage $\dot{V}O_{2\,max}$ during school time compared to both free play and nutritionally normal boys. Nutritionally normal boys, on the other hand, had less vigorous involvement in free play compared to physical activity during school time (Spurr and Reina, 1990).

Nutritionally normal (3rd and 4th grade) boys in Texas report 1.6 times more moderate to vigorous physical activities before and after, than during, school (Simons-Morton et al., 1990). The lower level of physical activity during school time of undernourished children could be energy conservation in undernourished populations, which is often alluded to in the literature (Spurr and Reina, 1990). Additionally, many children from low SES families are required to be active participants in the home and income generation for the family, which often requires higher energy expenditure in non-school time.

Disease states alter nutritional status and affect habitual physical activity. In a study of the effect of treatment for helminth infections on the growth, nutrition and physical activity of Kenyan children (7.5 years of age), Stephenson et al. (1994) observed a 43% increase in free-play activity after albendazole-treatment for helminth infection. This increase was significantly greater than that for a placebo group. Structured activity levels increased for both groups in the second exam, with a 53% increase in the treatment group compared to the 33% increase for the placebo group.

Goslin and Burden (1986) estimated the physical activity of South African European, African and "Colored" secondary school students (Table 15). Self-reported physical activity was assigned values of 8 (inactive), 9 (fairly active), 10 (active), and 11 (very active). European males had the highest physical activity levels, while African females had the lowest activity levels. Statistical significance was not indicated. The authors concluded that the ethnic-related differences in physical activity were reflected in performance-related fitness tests, and argued that the differences in the performance tests were most likely to be an artifact of the culture and experience of the groups. Differences in activity participation at school and after school, weekend-weekday differences, and the context of physical activity such as sport or waged labor were factors that could bias the results and conclusions of this study. Also, habitual physical activity was rated on a limited scale (8 to 11) that reduced the range of possibilities to just four categories.

Table 15. Estimated activity level (SD) of South African European, "Colored" and African adolescent males.[a]

	European	African	"Colored"
Age	16.8 (±0.8)	18.6 (± 1.4)	18.0 (± 1.5)
Activity level	10.0 (±0.8)	9.9 (± 0.5)	9.0 (± 0.5)

[a] Adapted from Goslin and Burden (1986).

The energy expenditure of Taiwanese school children (12 to 14 years of age), was estimated using the Bouchard et al. (1983) protocol (Huang, 1994). The age-specific health-related physical fitness of boys in the lowest and highest quartiles of mean daily total estimated energy expenditure (kcal/day) were compared. Boys in the lowest quartile of mean daily total estimated energy expenditure were taller and heavier, took significantly longer to complete the mile run and had less flexibility of the back on the sit and reach tests compared to boys in the highest quartile of mean daily total estimated energy expenditure. Boys with high mean daily total estimated energy expenditure performed better on health-related fitness tests.

Summary

The stratification of apartheid capitalism in South Africa has resulted in SES, growth, and nutritional status differences that are largely differentiated on the basis of race. SES and ethnicity are inextricably bound. In developing countries, indigenous populations are of lower SES compared to immigrant populations. In South Africa Africans have the lowest HDI and Europeans the highest HDI. These differences in the standard of living are manifest in nutritional status and growth differences. In general, Europeans are taller and heavier than African, "Colored" and Indian subjects of the same age.

Physical fitness is a combination of environmental and genetic factors that include culture, maturity, SES, ethnicity, nutritional status, growth, health, and habitual physical activity patterns of children. Nutritionally normal children have better physical performance-related fitness scores compared to undernourished and overweight boys. The data suggest that South African European boys have superior performance- and health-related fitness scores compared to African and Indian boys. Africans, on the other hand, have the lowest motor performances and physical fitness scores. Similar ethnic, SES and/or nutritional status differences in growth and performance have been found in Bolivia, Brazil, Colombia, India, Mexico and Zaire.

Physical fitness is related to the habitual activity levels of children, but the correlations are low to moderate. There is a need to clarify the relationship, if any, between habitual physical activity and fitness is different populations. There is evidence to indicate that habitual physical activity affects working capacity, the quality of life and productivity of an individual. The causal relationship between low $\dot{V}O_{2\,max}$ and habitual physical activity has not been addressed.

Habitual physical activity is affected by environmental factors that are closely tied with SES. Lower SES children have fewer opportunities to participate in habitual physical activity. On the other hand, despite the availability of space, undernourished children tend to engage in lower intensity habitual physical activities during the school day, whereas nutritionally normal children engage in higher levels of physical activity at school compared to free time. Thus, the level of habitual physical activity is determined by factors other than nutritional status or SES alone.

While the effects of SES, race and nutritional status on growth status have been addressed, there is a lacuna in the knowledge on the interaction effects of SES and race on nutritional status, and specifically what race and SES mean in the nutritional status of different populations in South Africa. There is a need to identify and address the effects of each of these factors and the potential confounding influences of these variables on the growth and physical performance of children.

Chapter 3

METHODS

The purpose of the study was to investigate the effects of socioeconomic status (SES), race, and nutritional status on the growth status, physical fitness and habitual physical activity of 10 year old South African boys of European, African and Indian ancestry. Data on sociodemographic characteristics, growth, estimated body composition, performance- and health-related fitness, and habitual physical activity were collected between 10 March and 11 June 1997. Permission to conduct the study and recruit subjects was solicited from approximately 30 schools; 25 schools indicated a willingness to participate in the study. The study was conducted at 18 of the 25 schools, due to the school calendar and time constraints.

South African schools

The end of the apartheid era has led to drastic rearrangement within South Africa, but large remnants of the apartheid era are still visible. The shortage of schools in traditional African townships and in peri-urban informal settlements resulted in large scale commuting to schools. A large proportion of government school populations are bussed in from the traditionally disadvantaged areas. They account for 20% to 80% of the school populations. Schools are divided into three major categories: Government, Model-C and Private.

Schools that are predominantly subsidized by the state, "Government schools," are those in the former Black, Indian and "Colored" residential areas, and include some of the larger and poorer schools in former White residential areas. School fees at the Government schools range from R150 to R600 per year.

Model-C schools are semi-private. School fees are higher than government schools and range from R1,200 to R3,600 per year. These fees are used to employ more teachers and reduce the pupil-teacher ratio below 45:1 found in Government schools, and for the improvement of facilities (both movable and fixed). Model-C schools are the schools of choice for middle and upper middle class parents. Public education scholarships funded by the national lottery are given to some students to attend some of the Model-C schools. Overall, Model-C schools have more affluent students than the Government schools.

Private schools receive no government funding and generally have greater flexibility and extensivity of the curriculum. School fees at the Private schools range from R6,000 to R24,000 a year. A small proportion of the students are on academic scholarships.

Subjects

There was great reticence among upper SES parents for their children to participate in the study. Many Model-C schools in the predominantly White upper middle class suburbs did not grant permission for the study. A similar reluctance to participate was expressed at most Private schools. There was a high refusal rate among predominantly White Model-C and private schools. Further, at schools which granted permission, parental consent was low. The main reason for the refusal was that the parent-teacher associations did not want the academic programs to be disrupted. It was thus, very difficult to recruit subjects of European (White) ancestry. This is an inherent bias in the present sample since the majority of the higher SES and European boys were excluded from this study.

Subject selection was based on the area in which the school was located, since schools drew the majority of their constituencies from the areas in which they were located. However, many students were bussed to Government schools from other areas, but the actual percentage of students bussed was not ascertained. Boys attending Public schools in traditionally low SES regions were classified as lower SES, while boys attending schools in higher SES residential areas were categorized as higher SES. Additionally, teachers were asked to assist in classifying the boys into "affluent" and "indigent" categories because school admission was not restricted to children from a specific residential area.

At the time of testing, all subjects were between 10.0 and 10.99 years of age. Permission to conduct the study was obtained from the principals of schools. In addition, all subjects read and understood the human subject forms, which was approved by the University Committee on Research Involving Human Subjects (UCRIHS) at Michigan State University, and had signed parental consent and subject assent forms on file

(Appendices A, B and C). The overall parental and student response was less than 50%, but ranged from 7.8% to 100% at the different schools.

Three hundred and eighty six boys between 10.00 and 10.99 years of age, attending schools in the greater Johannesburg area (Gauteng), South Africa, were subjects. The traditional classification of race in South Africa was used, i.e., an anthroscopic appraisal as it is offensive and politically incorrect to ask people to classify themselves by race. One of the major social changes that occurred in the post-apartheid South Africa was the removal of classification by race. Homeroom teachers helped to classify children and all children of mixed race were excluded from the study. Approximately 40% of boys in the schools sampled were excluded from the study by virtue of their race, i.e., of mixed ancestry and immigrant origin.

Sociodemographic Questionnaire

Parents (or surrogate parents) of each subject completed the sociodemographic questionnaire. This questionnaire established date of birth, age, race, area of residence, household size, SES, and a gross health history (Appendix D). In two "parent" families, the SES was based on midparent education, occupational prestige rating and income. If the child came from a single parent family, SES was based on the level of education, occupational prestige and income of the head of the household.

Occupation was categorized using the occupational prestige ratings for South Africans (Schlemmer and Stopforth, 1979). Since occupational prestige is not uniform across population groups in South Africa, Schlemmer and Stopforth (1979) provided adjusted occupational prestige ratings for Africans. Occupational prestige ratings ranged from 15 for unskilled manual labor to 84 for independently employed professionals. Income of the head of the household was divided into six categories (Table 16). Occupancy ratio (the number of people per room) was calculated as the number of rooms in the house, divided by the number of people who lived in the house.

Table 16. Income of the head of household per month and per year in South African Rands and U.S. Dollars.[a]

		Income	
Category	Recorded as	per month	per year
1	R208	R417 ($87)	less than R5,000 ($1,042)
2	R635	R417 to R833	R5,000 to R10,000
		($87 to $174)	($1,042 to $2,083)
3	R1,052	R834 to R1,667	R10, 001 to R20, 000
		($174 to $347)	($2,084 to $4,167)
4	R2,001	R 1,668 to R3,334	R20, 001 to R40, 000
		(S348 to $695)	($4,167 to $8,333)
5	R5,001	R3,335 or R6,667	R40,001 to R80,000
		($695 to $1.388)	($8,334 to $16,667)
6	R6,668+	R 6,668 ($1.389)	more than R80,000 ($16,667)

[a] Conversions are based on the exchange rate of four rand and fifty cents (R4.80) to one U.S. dollar ($1) in March, 1997.

Education was classified according the number of years of formal education, and was assigned the following scores:

0	no formal schooling
4	some elementary education
7	completed elementary school
10	some high school
12	completed high school
13	technical education or some college/university
15	college/university degree
17	graduate and post-graduate degree

Since education, occupational prestige and income were rated on different scales, all variables were converted into a common 5 point scale. Scaling values were calculated as follows: education weight = 17/5; occupation weight = 84/5; income weight = 8/5. Raw scores were then converted into scaled values as follows: education (score * 0.294); occupation (score * 0.006) and income (score * 0.625). The SES score was calculated as follows:

$$SES = (\text{education score} + \text{occupational prestige} + \text{income})/3.$$

A score of 3.00 was used as the SES cutoff (higher > 3.00, lower SES ≤ 3.00). In the absence of SES data, 92 boys were classified as higher (n=56) or lower (n=36) SES based on the location of the school and teacher ratings of SES.

Nutritional status was classified on the basis of BMI-for-age using the U.S. reference data of Must et al. (1991). Boys with a BMI-for-age ≤ 15 percentile were classified as undernourished. Boys with a BMI-for-age ≥ 85th percentile were classified as overweight. Boys with a BMI-for-age >15 and <85th percentile were classified as nutritionally normal. The breakdown of the sample by race and SES is summarized in Table 17.

Table 17. Total sample by race and SES.

	Sample size
African	
Lower SES	101
Higher SES	107
Indian	
Lower SES	38
Higher SES	99
European	
Higher SES	41
Total sample	386

Procedures

A battery of items which included anthropometry, tests of physical fitness, and physical activity questionnaires was used. Sociodemographic information was obtained from parents/guardians.

Anthropometry

Anthropometry is routinely used to assess the growth and nutritional status of a population (WHO, 1976), and to document within and between population variation. Anthropometric dimensions included indicators of attained size, skeletal robustness, relative muscularity and subcutaneous fat. All anthropometric dimensions were taken using the methods described in Lohman et al. (1988). Bilateral measurements were taken on the right side of the body. Skinfolds were taken with a Holtain (Harpenden) caliper to the nearest 0.1 millimeter. Height, sitting height, and biiliac and biacromial breadths were measured to the nearest millimeter with a Siber-Hegner (Martin) anthropometer. Elbow and knee breadths were taken to the nearest 0.5 millimeter with a small sliding caliper. Mass was measured to the nearest 100 grams on a calibrated Healthometer Professional scale. All circumferences were taken to the nearest millimeter using a retractable, nonstretchable flexible tape.

Measurements.

Body mass (body weight) was measured on a leveled platform scale with the subject dressed in light clothes and in bare feet.

Stature, or standing height, was measured with an anthropometer. The subject was barefooted and body weight was evenly distributed on both feet with heels together. The shoulders were relaxed with the arms hanging freely at the sides. The head was positioned in the Frankfort horizontal plane. A gentle upward stretch was applied to the neck area. The measurement was taken as the distance from the vertex of the skull to the floor.

Sitting height was a measure of the distance from the sitting surface to the vertex of the skull. Sitting height was obtained by having the subject seated erect on a table with the legs hanging freely over the edge of the table. The head was in the Frankfort horizontal position. A gentle upward stretch was applied to the neck area. The vertical distance between the vertex of the skull and the table surface was recorded.

Relaxed arm circumference was taken with the subject standing erect with the hands at the sides and the palms facing the thighs. The midpoint between the olecranon and acromial processes was the level of measurement. It was marked on the arm. The tape was placed around the midpoint of the arm so that it touched the skin, but did not compress the underlying soft tissues, and was positioned perpendicular to the long axis of the arm over the marked points.

Calf circumference was taken with the subject standing and body weight evenly distributed on both feet. A tape measure was positioned horizontally around the calf and moved up and down to locate the level of maximum circumference in a plane perpendicular to the long axis of the calf. This level was marked. The tape was in contact with the whole circumference but did not indent the skin.

Biacromial breadth was taken from the rear of the subject with the upper end of the anthropometer. The subject stood with the heels together and the arms hanging at the sides. The shoulders were relaxed, downwards and slightly forward so that the maximal reading could be taken. The most lateral borders of the acromial processes were palpated and the measurement was taken across the most lateral borders of the acromial processes.

Bicristal breadth was also taken from the rear. The subject stood with his feet 5 cm apart to prevent swaying, with the arms away from the area measured. The iliac crests were palpated and the measurement was taken with the upper end of the anthropometer applied downwards at a 45° angle, with firm pressure, across the maximum breadth of the iliac crests.

Biepicondylar breadth was taken with a small sliding caliper as the distance between the epicondyles of the right humerus to the nearest 0.5 mm.

Bicondylar breadth was taken with a small sliding caliper with the subject sitting and the right knee flexed at 90°. The medial and lateral epicondyles were palpated and the distance between the medial and lateral condyles of the femur was measured. Firm pressure was applied as the distance between the condyles was measured to the nearest 0.5 mm.

Triceps skinfold was taken as a vertical fold at the same level as relaxed arm circumference, midway between the acromial and olecranon processes in the midline on the posterior aspect of the arm over the triceps muscle.

Biceps skinfold was taken as a vertical fold on the anterior aspect of the arm over the biceps muscle at the same level as the triceps skinfold.

Subscapular skinfold was taken with the subject standing erect with his hands relaxed at the sides. The inferior angle of the scapula was palpated. A diagonal skinfold was picked up at approximately 45° to the horizontal plane following the natural cleavage lines of the skin below the inferior angle of the right scapula. The measurement was taken 1 cm inferior-laterally to the thumb and forefinger.

Suprailiac skinfold was measured in the midaxillary line immediately superior to the iliac crest. The subject stood with feet together in an erect position. An oblique skinfold was grasped just posterior to the midaxillary line following the natural cleavage lines of the skin.

Abdominal skinfold was taken as a horizontal fold 3 cm lateral to the midpoint of the umbilicus and 1 cm inferior to it.

Derived dimensions.

1. Skinfolds were used to estimate total subcutaneous fatness and relative subcutaneous fat distribution (Malina and Bouchard, 1988).
    - *Extremity skinfolds:* sum of the triceps and biceps skinfolds.
    - *Trunk skinfolds:* sum of the abdominal and subscapular skinfolds.
    - *Total skinfolds:* sum of five skinfolds.
    - *Trunk/Extremity ratio:*

      Σ of 2 trunk skinfolds/ Σ of 2 extremity skinfolds (mm/mm).

2. Estimated leg (subischial) length:

   stature minus sitting height.

3. Arm musculature (Malina, 1995b):

arm muscle circumference (cm) = $C_a - \pi/2\ (S_t + S_b)$

arm muscle area (cm^2) = $1/(4\ \pi)\ [Ca - \pi/2\ (S_t - S_b)]^2$

where: C_a is arm circumference (cm)

S_t is triceps skinfold (cm)

S_b is biceps skinfold (cm).

4. Sitting height/stature ratio, an estimate of relative trunk or leg length:

sitting height/standing height x 100.

5. Bicristal/biacromial breadth ratio, an indicator of the configuration of the trunk in terms of relative shoulder and hip proportions:

bicristal/biacromial x 100.

6. Body mass index (BMI):

weight (kg) / height $(m)^2$.

Technical errors of measurement.

All measurements were taken by the researcher. Intra-observer measurement variability was calculated on replicate measurements of 10% of the sample, taken about four days after the first set. The technical error of measurement was calculated (Malina et al., 1973):

$$\sigma_e = \sqrt{\Sigma d^2/2n}.$$

It is defined as the square root of the sum of the squared differences of replicates divided by twice the number of pairs. The intra-observor variability of the anthropometry was within ranges observed in studies on other populations (Table 18).

Table 18. Intra-observer technical errors of measurement in the present study (n=42) compared to those for several other studies.

	Present study	Katzmarzyk (1997)	Klika (1995)	Wellens (1989)	HES[a]	Zavaleta and Malina (1981)	Rocha Ferreira (1988)
Mass (kg)	0.14	0.72	0.23		0.53	0.48	0.23
Stature (cm)	0.41	0.54	0.21	0.19	0.49	0.54	0.35
Sitting height (cm)	0.31	0.95	0.22	0.20	0.53	0.69	0.38
Circumferences (cm):							
Relaxed arm	0.26	0.51	0.24	0.13	0.35	0.37	0.29
Flexed arm	0.21	0.40	0.20	0.17			0.38
Calf	0.24	0.34	0.25	0.13	0.87	0.30	0.45
Breadths (cm):							
Biacromial	0.34	0.57	0.18	0.17	0.54	0.72	0.34
Bicristal	0.34	0.58	0.26	0.15	0.71	0.24	0.38
Biepicondylar	0.07	0.10	0.12	0.04	0.12	0.07	0.10
Bicondylar	0.07	0.84	0.16	0.04	0.11	0.06	0.10
Skinfolds (mm):							
Triceps	0.46	0.94	0.23	0.15	0.80	0.51	0.55
Biceps	0.32	0.96	0.34			0.58	0.19
Subscapular	0.29	0.03	0.34	0.17	1.83	0.55	0.26
Suprailiac	0.32	1.13	0.60	0.24	1.87	0.55	0.26
Abdominal	0.55	1.64	0.41			0.89	0.55

[a]U.S. Health Examination Survey; Johnston et al. (1972); Malina et al. (1973).

__Physical fitness.__

Tests of health-related and performance-related fitness were used. Physical fitness testing is routinely performed as part of the Physical Education curriculum in South Africa and students were familiar with the battery of tests used in this study. Health-related fitness was assessed using the 9 minute run, sit-ups, push-ups, and the sit and reach. Performance-related fitness was assessed using the 50 meter dash, grip strength, standing long jump, and shuttle run.

Research assistants conducted six of the performance- and health-related fitness tests: 9 minute run, 30 second sit-ups and push-ups, dash, long jump and shuttle run. The sit and reach and grip strength tests were conducted by the author. The best of three trials were recorded for grip strength, sit and reach, and the standing long jump. The better of two trials were used for the dash. An all out single effort was used to record the 9 minute distance run, push-ups, sit-ups, and the shuttle run.

Measurement of Physical Fitness

9-minute run-walk provided an indicator of cardiorespiratory fitness. Subjects ran-walked the greatest distance that they could in 9 minutes. Most tests were conducted on makeshift asphalt or grass surfaced 200 to 400 meter tracks, but some tests were conducted on makeshift 100 meter tracks. The subject assumed a standing start at the starting line on the command 'Get Ready'. On the command 'Go', the subject jogged and/or walked around the track continuously for nine minutes. After each lap the subject was informed of how many minutes of the run were left. The countdown provided both incentive for continued participation as well as cues for pacing the run. When the whistle was blown to signal the end of the nine minutes, the subject stopped where he was and sat down on the ground. The run was scored in terms of distance completed to the nearest 10 meters.

50-meter dash was a measure of running speed. The test was conducted on a track where possible. However, in some instances, the sidewalk or grass surfaces were used. A short warm-up period preceded the dash. The subject assumed a standing starting position at the starting line on the command 'Get Ready'. On the command

'Go', the subject ran as fast as possible to a point beyond the 50 meter mark. This overrunning technique was used to maintain maximum acceleration throughout the dash. The time elapsed to the nearest 0.01 second between the starting signal and crossing of the finish line was record as the score.

Grip strength was a measure of static strength. The subject held an adjustable Stoelting dynamometer comfortably in the right hand in line with the forearm. It hung down beside the thigh. The second joint of the hand was fitted snugly under the handle and took the weight of the instrument. The dynamometer was gripped between the fingers and the palm at the base of the thumb. The firmly held dynamometer was raised clear of the body and no contact with the body was allowed. During the squeezing of the dynamometer, the arm was not allowed to swing or perform a pumping motion. Each trial was recorded to the nearest 0.5 kilogram.

Modified push-ups for males provided a measure of endurance of the arm and shoulder girdle musculature. The subject lay face down on the floor. The body was straight with the arms bent and hands flat on the floor beneath the shoulders. The lower legs were crossed with the knees bent. The subject pushed upward to a straight arm position, lowered his body until his chest touched the floor, and repeated the exercise as many times as possible in 30 seconds (Chrysler Fund/Amateur Athletic Union, 1993-1994).

Shuttle run was a measure of speed and agility. Two parallel lines 120 cm long, were drawn on the floor 5 meters apart. Two cones marked the end of each line. The subject stood behind one of the lines, with one foot just behind the line. On the signal

'Go', the subject ran to the other cone, crossed that line with both feet, returned to the starting line and crossed the starting line with both feet, as quickly as possible. The subject completed five of these cycles as quickly as possible. To guard against deceleration at the end of the fifth cycle, the overrunning technique as in the dash was used. The score was the time, in tenths of a second, taken to complete five cycles (Beunen et al., 1988).

Sit-ups provided a measure of abdominal strength and muscular endurance. The subject assumed a supine position on a mat with the knees flexed and heels flat on the mat. The arms were crossed on the chest with the hands on opposite shoulders. The subject's feet were held down by a partner. On the 'Go', signal, the subject curled up to touch his knees with his elbows, and curled back to the floor until the midback contacted the mat. The subject performed as many sit-ups as possible in 30 seconds. Only completed sit-ups were counted.

The *standing long jump* was a test of explosive power. The subject stood behind the take-off line with his feet at a natural distance apart. In the preparation phase of the jump, the subject bent at the knees and simultaneously swung his arms backwards. The subject jumped forward by extending at the knees and simultaneously swinging his arms forward. The subject took off with both feet simultaneously, jumped forwards and landed as far away from the take-off line as possible. If the subject fell backwards, or took off on one foot, another trial was given. The distance to the nearest 0.5 cm between the point of contact closest to the take-off line and the take-off line was measured as the distance of the jump.

Sit and reach evaluated the flexibility of the lower back and posterior thighs. The subject sat down at the test apparatus with knees fully extended and the bare feet shoulder width apart. Feet were flat against the end board. Arms were extended forward with the hands placed on top of each other. The subject reached directly forward, palms down, along the measuring tape four times and held the position of the maximum reach of the fourth trial. The position of the maximum reach was held for one second. The most distant point reached on the fourth trial was measured to the nearest 0.5 centimeter

Within-day and between day reliabilities were calculated on 10% of the sample (Tables 19 and 20). The first and third measurements were used to calculate the within day reliability. Between day reliability was calculated on measurements taken four days apart.

Table 19. Within day correlations of fitness tests of trials one and three for 42 boys with comparative data for three other samples.

	Present Study South African boys	Malina and Buschang (1985) Mexican (Oaxaca) children	Malina and Moriyama (1991) Philadelphia children	Rocha Ferriera (1988) Brazilian children
	1st and 3rd	1st and 2nd	best and 2nd best trials	1st and 2nd
Dash	0.74	0.71 to 0.89	0.39 to 0.98	0.84
Grip	0.96	0.63 to 0.97	0.79 to 0.98	0.99
Sit and reach	0.92			
Standing long jump	0.97	0.82 to 0.94	0.72 to 0.95	0.99

Diaries and Questionnaires

A 3-day physical activity self-report and a habitual physical activity questionnaire were completed by subjects and a sociodemographic questionnaire was completed by

Table 20. Between day correlations of fitness tests taken four days apart with comparative data for Brazilian children.

	Correlations	
	Present Study	Rocha Ferreira (1988)
Dash	0.53	0.74
Grip	0.95	0.95
Nine minute run	0.92	0.68
Push-ups	0.98	
Shuttle run	0.79	
Sit and reach	0.95	
Sit-ups	0.95	
Standing long jump	0.96	0.69

parents or guardians. Subjects completed the questionnaires and the diaries under the supervision of the researcher or research assistants.

Physical activity questionnaire.

Physical activity data were collected using the Bouchard et al. (1983) protocol (Appendix E), which was adapted by dividing the day into meaningful segments as opposed to 15 minute intervals. The day was divided into meaningful segments (before school, before first recess, first recess, before second recess, second recess, after second recess, after school, afternoon, before supper, after supper) to increase the accuracy of reporting (Baranowski et al., 1984). The research assistant who administrated the questionnaire prompted subjects to provide estimates of the duration of activities to the nearest 15 minutes.

The physical activity questionnaire was a retrospective 24-hour recall. Activities of the preceding 24 hours were recalled and recorded. All efforts were made to have the subject recall the activity for one weekend day and two weekdays. The questionnaire was administered on three successive school days -- Monday, Tuesday and Wednesday; or Thursday, Friday and Monday. Activities of the preceding day (Sunday, Monday and Tuesday; or Wednesday, Thursday and Sunday) were recalled. This ensured that a weekend day (Sunday) was included in the survey. Activity questionnaires were administered at the same time each day to ensure continuous coverage of the three day period.

The Bouchard et al. (1983) protocol was used in an interview format with individual children. A list of activities was given to each subject along with the 24-hour record. The subject was prompted and significant events such as before and after breakfast were used to trigger the recall of the events of the previous day. The researcher asked the subjects the following types of questions to prompt and cue recall:

- What time did you get up and go to bed?
- Did you participate in any domestic chores related to the activity (cleaning, preparing meals, tending to garden, cleaning the car, etc.)?
- What did you do immediately before or after a meaningful event (getting up, breakfast, school, first recess, second recess, after school, before snack, after snack, before supper, after supper, before bed, bedtime) in the day?
- How did you move (run, walk, hop, skip, fast, slow, moderate) about from one location to another?
- How much of effort (sweating, hyperventilating, tired) was involved in the activity?

- In what types of activities (games, watching television, reading, solitary hobbies, etc.) did you engage?
- Were you engaged in extracurricular activities (choir, ballet, drama, martial arts, sport clubs, etc.)?
- What television program was on? Or what television programs did you watch?

The amount of time and the estimated energy expenditure in sedentary (1-2 METS), light (3-5 METS) and moderate-to-vigorous physical activity (MVPA, 6-9 METS) were estimated for each day, based on the criteria (Table 21) of Bouchard et al. (1983). The mean amount of time spent in light and MVPA, as well as total daily estimated energy expenditure and energy expenditure in MVPA for each 15 minute segment, were calculated.

The physical activity of 57 subjects was observed during recess and lunch breaks on the second day at the school. Activity observations were recorded as accurately as possible and the time spent on each activity was recorded to the nearest five minutes. The energy expenditure (METS) was calculated. The reliability of the recall records were compared with the observed physical activity records. There was a high positive correlation ($r = 0.89$) between observed and recalled physical activity in this subsample. The correlation was similar to the correlation ($r = 0.84$) between observed and recalled physical activity reported by Baranowski et al. (1984). Although there was reasonable consensus between recalled and observed physical activity, there was a significant difference in the accuracy of the recalled values (Table 22). The boys reported higher levels of habitual physical activity compared to observed values.

Table 21. Activity Code Sheet (after Bouchard et al., 1983).

METS	Example of activities in this code
1	Sleeping, resting in bed
2	Sitting: eating, listening, writing, reading, studying, watching TV
3	Light activity standing: washing, combing my hair, cooking, and similar activities
4	Slow walking (less than 4 kilometers per hour), driving a motorcycle, dressing, showering, and similar activities
5	Light manual work: household chores such as sweeping the floor, washing windows, vacuuming, painting, waiting on tables, walking at 4 to 6 km/hr -- 1 km in 10 to 15 minutes
6	Leisure activities and sports in a recreational environment: baseball/softball, cricket, field hockey, golf, volleyball, canoeing or rowing, cycling (less than 10 km/hr), table tennis, and similar leisure/recreational activities, drama classes
7	Manual work at a moderate pace: carpentry, raking and mowing the lawn loading and unloading goods, chopping wood, and similar activities
8	Leisure and sport activities of higher intensity (not competitive): canoeing (5 to 8 km/hr), bicycling (more than 15 km/hr), dancing, water skiing, badminton, gymnastics, swimming, tennis, horse riding, fitness exercises like calisthenics, walking (more than 6 km/hr), karate, judo, etc.
9	Intense manual work, high intensity sport activities or sport competition: karate, judo, jogging and running (more than 9 km/hr), racquetball, handball, squash, badminton, tennis, swimming, hiking, rugby, soccer, carrying heavy loads, aerobic dance, and similar intense activities

Table 22. Means, SD, correlations and ANOVA for observed and recalled estimated energy expenditure (kcal/day) in physical activity of 57 boys.

	Recess		Lunch		Total	
	M	SD	M	SD	M	SD
Observed	12.77	4.35	16.04	6.29	28.81	9.19
Reported	18.47	8.46	18.32	8.40	36.79	14.69

	Correlation		Sum of squares	df	Mean square	F
Recess	0.86**	Between Groups	787.20	5	157.44	29.65**
		Within Groups	270.83	51	5.31	
		Total	1058.04	56		
Lunch	0.86**	Between Groups	1687.52	6	281.25	26.51**
		Within Groups	530.42	50	10.61	
		Total	2217.93	56		
Total	0.89**	Between Groups	3914.69	11	355.88	19.77**
		Within Groups	810.19	45	18.00	
		Total	4724.88	56		

**$p<0.01$

Habitual Physical Activity

The Physical Activity Questionnaire for Older Children (PAQ-C) was used to collect habitual physical activity data (Appendix F) (Kowalski et al., 1997). The PAQ-C is a self-administered 7-day recall questionnaire. Nine items assessing the habitual physical activity of children were scored on a 5-point scale and were used to derive the total activity score. Higher scores indicated higher levels of activity. Six questions assessed activity in physical education classes, recess, lunch, immediately after school, in the evening, and on weekends. One question asked the subject to categorize his activity for the last seven-days based on five descriptions ranging from low to very high activity levels. Another question required the subject to list how many times he had engaged in physical activities for each day of the preceding week. The last question was an activity checklist consisting of common sports, leisure activities and games, and had room for the subject to list any other activities that he commonly participated in that were not included on the checklist. The primary purpose of this item was to act as a memory cue. The PAQ-C score which ranges from 1 to 5, was calculated:

PAQ-C score = [(Σ of scores for questions 1 through 8) + (total score for question nine/ number of items checked on activity checklist)] / 9.

Statistical Analyses

Descriptive statistics were calculated for all variables; SES-specific, race-specific and nutritional status-specific descriptive statistics were also calculated. Multivariate analysis of variance (MANOVA) was used to answer the question: "What is the relationship of SES, race and nutritional status to the growth status, physical fitness and habitual physical activity of 10 year old South African boys?".

SES, race and nutritional status were entered as independent variables with growth (stature and mass), proportions (sitting height/stature ratio; bicristal/biacromial ratio), body composition (Σ of 5 skinfolds; trunk/extremity ratio; estimated arm musculature), individual fitness tests, estimated energy expenditure and habitual physical activity as the dependent variables.

To specifically answer research question one: Are there any SES, race and nutritional status differences in the growth status and physique of 10 year old South African boys?" MANOVA and MANCOVA were performed. Anthropometric variables were categorized as size attained, body proportions, and body composition.

Analysis of covariance (ANCOVA) was used to determine SES-specific, race-specific and nutritional status-specific differences in growth status. SES, race and nutritional status were the covariates. MANOVA was used to calculate the interaction of SES, race and nutritional status on growth status. Specific between group differences for all significant MANOVAs and MANCOVAs were tested using the Scheffé Post hoc test and pairwise comparisons of estimated marginal means when SES, race and/or nutritional status were used as covariates.

To specifically answer research question two: "Are there race, SES and nutritional status differences in the health-related and performance-related fitness of 10 year old South African boys?", MANOVA and ANOVA were conducted. Components of health-related fitness included sit-ups, push-ups, 9 minute run, sit and reach and the sum of 5 skinfolds, while components of performance-related fitness included the dash, shuttle run, grip strength and the standing long jump. The effects of race, SES and nutritional status were considered individually, while the other two independent variables were entered as covariates. Between group differences for all significant ANOVAs and ANCOVAs were identified using the Scheffé Post Hoc test and pairwise comparisons of estimated marginal means, respectively. Multiple and stepwise regression analyses were performed to determine which sociodemographic factor or factors (SES, race and/or nutritional status) was and/or were significant predictor/s of health- and performance-related fitness items.

To specifically answer research question three: "Are there SES, race and nutritional status differences in the habitual physical activity of 10 year old South

African boys?" MANOVA was performed. Estimated energy expenditure was sorted into sedentary (1 - 2 METS), light (3 to 5 METS), MVPA (6 - 9 METS) and total daily energy expenditure. Multiple and stepwise regression analyses were conducted to determine which sociodemographic factor/s (SES, race and nutritional status) was and/or were the most powerful predictor/s of sedentary, light and moderate to vigorous physical activity.

To specifically answer research question four: "Are there nutritional status differences in race-specific habitual physical activity of 10 year old South African boys?" MANOVA was performed. The effects of SES were controlled statistically. Estimated energy expenditure was sorted into sedentary (1 - 2 METS), light (3 to 5 METS), MVPA (6 - 9 METS) and total daily energy expenditure. Stepwise regression analyses were conducted to determine if nutritional status was a powerful predictor of sedentary, light and moderate to vigorous physical activity.

To specifically answer research question five: "Are there race-specific differences in the growth status and physical fitness of 10 year old South African boys of African, Indian and European ancestry with different levels of energy expenditure?", race-specific differences in the growth and physical fitness of boys in the lowest (< 25th percentile) and highest (> 75th percentile) quartiles of MVPA and total energy expenditure (kcal/kg) were compared using ANCOVAs with the SES as the covariate. Pairwise comparisons of estimated marginal means and Scheffe post hoc comparisons of significant MANCOVAs and MANOVAs were used.

Power of statistical analyses.

The sample size is large enough to provide adequate statistical power. Adequate power (i.e., > 0.70) for multivariate analyses (MANOVA and MANCOVA) at an alpha of 0.10, for two through seven variables at a moderate overall effect size of 0.64 requires about 30 subjects per group (Stevens, 1980). The sample size that will provide adequate power in regression analyses is roughly calculated as 15 subjects per variable (Stevens, 1992). Thomas et al. (1997) posit that setting power at 0.8 adjusts the level of Type II errors to an acceptable one. Estimated sample size, based on the tables of Cohen (1988), with an effect size of 0.5 and high power (0.8), would require a minimum of 26 subjects per group.

The regression analyses that were calculated were to determine if ethnicity, SES, or nutritional status were predictors of physical fitness and estimated energy expenditure. This analysis, using three variables, required a minimum of 45 subjects from each SES group to provide adequate power. The sample sizes for higher (n = 101) and lower (n = 107) SES African, and higher (n = 99) SES Indian boys were large enough to satisfy the criteria for power stipulated by both Stephens (1992) and Cohen (1988). The sample sizes of lower SES Indian (n = 38) and European boys (n = 41), on the other hand, were smaller than recommended, indicating a lower power to predict the trends for European and lower SES Indian boys

Chapter 4

RESULTS

The study examines the relationship of race, SES and nutritional status to the growth status, physical fitness and habitual physical activity of 10 year old South African boys of African, Indian and European ancestry. The results are presented in four parts: growth; physical fitness; habitual physical activity; and relationships among habitual physical activity, growth status and physical fitness.

Descriptive Statistics

Means (M), standard deviations (SD), and medians (md) where appropriate, for all variables for the total sample are shown in Table 23. Corresponding statistics by race are shown in Table 24. Summary ANOVAs of differences among the three racial groups and Scheffé post hoc tests are shown in Table 25.

Descriptive statistics by race (SES combined in African and Indian boys) are summarized in Table 24. Between group differences for all significant ANOVAs, which required F values larger than 2.95 and 4.50, for $p<0.05$ and < 0.01, respectively, with two degrees of freedom, were tested with the Scheffé post hoc test (Table 25). Height and mass do not differ among the groups. European boys, however, have longer sitting heights than Indian and African boys, who do not differ significantly.

Table 23. Sample sizes, means, standard deviations, ranges and medians (where appropriate) for all variables in the total sample.

Variables	N	Mean	SD	Median	Min	Max
Age, yrs	389	10.5	0.3		10.0	11.0
Mass, kg	389	32.7	6.9	31.5	15.8	61.6
Stature, cm	389	138.4	6.6		120.6	160.4
BMI, kg/m^2	386	16.9	2.7	16.4	10.0	29.5
Leg length, cm	386	68.6	4.8		53.0	87.9
Sitting height, cm	386	69.7	3.6		59.0	81.0
Sitting height/Stature, %	386	50.4	1.9		43,.7	57.4
Skinfolds, mm						
Biceps	386	6.9	4.0	5.8	2.3	25.0
Triceps	386	12.5	5.8	10.5	5.0	34.2
Subscapular	385	9.2	6.4	6.8	3.8	45.8
Suprailiac	386	7.7	5.6	5.6	2.2	36.4
Abdominal	386	12.1	8.1	8.9	3.4	42.0
Σ of Trunk	385	21.3	14.0	15.9	7.2	87.8
Σ of Extremity	386	19.4	9.4	16.2	8.0	59.2
Σ of 5	385	48.4	27.9	37.6	19.5	168.2
Trunk/Extremity, mm/mm	385	1.06	0.26	1.05	0.39	2.02
Circumferences, cm						
Relaxed arm	387	20.3	2.7	19.8	15.1	29.6
Calf	386	27.6	2.8	27.2	20.6	36.5
Arm muscle area, cm^2	386	30.5	8.5	28.5	16.6	66.3
Breadths, cm						
Biacromial	387	28.8	2.3		20.1	35.1
Bicristal	387	19.9	2.1		14.5	27.0
Biepicondylar	385	5.5	0.4		4.0	6.6
Bicondylar	386	8.1	0.5		6.7	9.8
Bicristal/biacromial, %	386	69.1	5.2		47.1	89.7

Table 23. (continued)

	N	Mean	SD	Min	Max
Physical fitness					
Dash, sec	382	9.5	1.2	8.0	15.1
Grip, kg	383	19.0	3.5	10.0	30.0
Grip, kg/kg mass	383	0.6	0.1	0.3	1.0
Shuttle run, sec	383	23.0	2.6	19.0	35.0
Standing long jump, cm	379	151.1	21.8	76.0	197.0
9-minute run, m	388	1622.0	376.0	560.0	2840.0
Push-ups, #/30 sec	384	25.0	8.0	1.0	46.0
Sit and reach, cm	383	26.2	6.0	6.0	39.5
Sit-ups, #/sec	386	17.0	6.0	2.0	39.0
Time spent in sedentary activities, 3 day mean, hours					
Television	337	2.7	1.6	0.0	10.0
Commute	350	0.6	0.6	0.0	2.9
Computer Games	337	2.9	1.7	0.0	10.0
Energy expenditure, 3-day mean, hours					
Sedentary	372	20.1	1.3	15.0	22.9
Light	333	2.6	1.0	0.8	6.1
MVPA	333	1.4	0.8	0.0	4.8
Energy expenditure, 3-day mean (kcal/day)					
Sedentary	328	721.8	170.2	333.6	1386.4
Light	328	260.0	126.9	51.6	829.4
MVPA	328	274.0	174.6	0.0	953.2
Total	328	1255.8	297.3	732.8	2360.5
Energy expenditure, 3-day mean (kcal/kg/day)					
Sedentary	328	22.0	2.0	16.7	28.2
Light	328	7.9	3.4	1.7	19.2
MVPA	328	8.6	5.4	0.0	29.6
Total	328	38.5	5.8	24.7	55.6
PAQ-C score	383	2.8	0.5	1.4	4.5

Table 24. Descriptive statistics by race.

	African				Indian				European			
	N	M	SD	Md	N	M	SD	Md	N	M	SD	Md
Age, yrs	209	10.5	0.3	10.5	139	10.5	0.3	10.5	41	10.5	0.4	10.5
Mass, kg	209	32.5	6.1	31.5	139	32.7	8.3	30.6	41	33.7	5.7	33.3
Stature, cm	209	137.9	6.4		139	139.0	6.9		41	139.2	6.4	
BMI, kg/m^2	209	17.1	2.6	16.6	139	16.6	2.9	15.9	41	17.4	2.6	17.4
Leg length, cm	209	68.4	4.7		139	69.3	5.0		41	67.5	4.2	
Sitting height, cm	209	69.4	3.7		139	69.7	3.6		41	71.8	2.9	
Sit Ht/Stat, %	209	50.4	2.0		139	50.2	1.9		41	51.6	1.2	
Skinfolds, mm												
Biceps	209	6.6	3.7	5.2	139	7.4	4.3	5.8	41	6.6	3.6	5.4
Triceps	209	11 .9	5.6	10.0	139	13.1	6.0	11.2	41	13.2	5.9	11.2
Subscapular	209	8.7	5.5	6.8	139	10.3	7.7	7.3	41	8.0	5.1	6.3
Suprailiac	209	6.9	4.6	5.4	139	8.9	6.8	5.9	41	7.5	5.2	5.6
Abdominal	209	10.8	7.0	8.4	139	14.1	9.5	10.6	41	11.7	7.2	9.7
Σ Trunk	209	19.5	12.1	15.4	139	24.3	16.7	17.6	41	19.7	11.8	15.9
Σ Extremity	209	18.5	9.0	15.2	139	20.5	10.0	17.3	41	19.9	9.3	16.7
Σ 5	209	45.0	24.7	36.8	139	53.8	32.2	41.0	41	47.0	25.3	38.8
TER, mm/mm	209	1.03	0.23	1.04	139	1.13	0.28	1.13	41	0.98	0.23	0.95
Circumference, cm												
Relaxed arm	209	20.2	2.5	19.7	139	20.3	3.1	19.6	41	21.0	2.5	21.0
Calf	209	27.7	2.6	27.3	139	27.3	3.1	26.6	41	28.1	2.7	28.3
Arm muscle area, cm^2	209	29.6	8.0	28.0	139	31.7	9.5	29.2	41	30.9	7.0	30.7
Breadths, cm												
Biacromial	209	28.6	2.4		139	28.6	2.3		41	29.8	1.3	
Bicristal	209	19.6	2.1		139	19.8	2.1		41	21.4	1.3	
Biepicondylar	209	5.5	0.4		139	5.5	0.4		41	5.6	0.4	
Bicondylar	209	8.1	0.5		139	8.1	0.5		41	8.3	0.5	
Bicr/Biac, %	209	68.4	4.9		139.	69.3	5.7		41	72.0	3.6	

Table 24. (continued)

	African			Indian			European		
	N	M	SD	N	M	SD	N	M	SD
Physical fitness									
Dash, sec	200	9.4	1.2	137	9.8	1.2	41	9.4	1.0
Grip, kg	205	19.3	3.6	136	18.6	3.4	41	19.3	3.0
Grip, kg/kg mass	205	0.6	0.1	136	0.6	0.1	41	0.6	0.1
Shuttle run, sec	205	23.0	2.5	137	23.2	2.8	41	22.5	2.2
Standing long jump, cm	205	150.5	21.5	137	149.8	21.9	41	157.7	21.9
9-minute run, m	205	1616.7	360.5	138	1556.2	336.9	41	1875.4	471.6
Push-ups, #/30 sec.	205	23.7	8.2	135	25.2	8.3	41	28.0	8.0
Sit and reach, cm	205	27.8	5.7	137	24.0	5.9	41	25.7	5.4
Sit-ups, #/30 sec.	205	16.4	5.3	138	16.5	5.9	41	17.2	5.5
Time in sedentary activities, 3 day mean, hours									
Television	179	2.2	1.3	121	2.5	1.7	41	1.4	0.8
Commute	179	1.4	0.9	121	0.2	0.4	41	0.4	0.7
Computer Game	179	0.1	0.3	121	0.2	0.6	41	0.6	1.2
Energy expenditure, 3-day mean, hours									
Sedentary	179	19.8	1.3	121	20.5	1.1	41	19.7	1.3
Light	179	2.8	0.9	121	2.3	0.9	41	2.9	1.0
MVPA	179	1.6	0.8	121	1.2	0.7	41	1.5	0.8
Energy expenditure, 3-day mean (kcal/day)									
Sedentary	179	719.0	155.8	121	732.7	194.6	41	692.6	144.8
Light	179	275.0	122.9	121	235.7	133.2	41	269.4	111.6
MVPA	179	305.7	175.4	121	219.2	152.2	41	307.8	204.9
Total	179	1299.7	273.0	121	1187.6	327.3	41	1269.8	263.7
Energy expenditure, 3-day mean (kcal/kg/day)									
Sedentary	179	22.0	2.0	121	22.3	1.8	41	21.3	2.5
Light	179	8.4	3.3	121	7.2	3.3	41	8.4	3.3
MVPA	179	9.6	5.5	121	6.8	4.5	41	9.6	6.1
Total	179	40.0	5.5	121	36 3	5.1	41	39.2	6.6
PAQ-C score	205	2.8	0.4	137	2.8	0.6	41	2.8	0.5

Table 25. Results of ANOVA (F ratios) and Scheffé post hoc tests for mean differences (MD) between races.

		Scheffé post hoc race differences		
Dependent variable	F	Race	Race	MD
Mass, kg	0.38	African	Indian	0.66
		African	European	0.72
		Indian	European	0.06
Stature, cm	1.17	African	Indian	-1.10
		African	European	-1.46
		Indian	European	-0.36
BMI, kg/m^2	2.56	African	Indian	0.70
		African	European	0.70
		Indian	European	0.00
Leg length, cm	2.35	African	Indian	-1.14
		African	European	0.57
		Indian	European	1.71
Sitting height, cm	4.06*	African	Indian	0.03
		African	European	-2.00*
		Indian	European	-2.07*
Sitting height/ stature ratio, %	5.74**	African	Indian	0.22
		African	European	-1.20**
		Indian	European	-1.42**
Skinfolds, mm				
Biceps	2.92	African	Indian	-0.60
		African	European	1.38
		Indian	European	1.98
Triceps	1.93	African	Indian	-0.92
		African	European	1.24
		Indian	European	2.16
Subscapular	3.20*	African	Indian	-1.15
		African	European	2.16
		Indian	European	3.30*
Suprailiac	5.38**	African	Indian	-1.81*
		African	European	1.18
		Indian	European	2.99*
Abdominal	5.01**	African	Indian	-2.83*
		African	European	0.82
		Indian	European	3.65
Σ of Trunk	5.28**	African	Indian	-4.82**
		African	European	-0.18
		Indian	European	4.65
Σ of Extremity	1.82	African	Indian	-1.94
		African	European	-1.28
		Indian	European	0.66
Σ of 5	4.24*	African	Indian	-8.81*
		African	European	-2.06
		Indian	European	6.75
TER, mm/mm	8.95**	African	Indian	-0.10**
		African	European	0.05
		Indian	European	0.15**
Circumferences, cm				
Relaxed arm	0.11	African	Indian	0.14
		African	European	0.12
		Indian	European	-0.02

* $p<0.05$ ** $p<0.01$

Table 25. (continued)

		Scheffé post hoc race differences		
Dependent variable	F	Race	Race	MD
Calf	0.64	African	Indian	-1.32
		African	European	1.37
		Indian	European	2.68
Estimated muscle area, cm^2				
Arm	2.72	African	Indian	-2.33
		African	European	-0.94
		Indian	European	1.39
Breadth, cm				
Biacromial	3.21*	African	Indian	0.40
		African	European	-0.73
		Indian	European	-1.13*
Bicristal	13.84**	African	Indian	0.25
		African	European	-1.84**
		Indian	European	-1.60**
Biepicondylar	0.24	African	Indian	-0.01
		African	European	-0.06
		Indian	European	-0.05
Bicondylar	0.60	African	Indian	0.01
		African	European	-0.12
		Indian	European	-0.12
Bicristal/biacromial ratio, %	6.01**	African	Indian	-0.93
		African	European	-3.69**
		Indian	European	-2.76*
Physical Fitness				
Dash, sec[a]	3.64*	African	Indian	0.36*
		African	European	0.05
		Indian	European	-0.41
Grip, kg	2.04	African	Indian	0.83
		African	European	-0.06
		Indian	European	-0.89
Grip, kg/kg mass	0.46	African	Indian	0.01
		African	European	-0.01
		Indian	European	-0.02
Shuttle run, sec[a]	0.24	African	Indian	0.21
		African	European	0.22
		Indian	European	0.01
Standing long jump, cm	0.53	African	Indian	0.10
		African	European	-4.51
		Indian	European	-4.61
9-minute run, m	7.29**	African	Indian	38.63
		African	European	-231.91**
		Indian	European	-270.54**
Push-ups, #/30 sec	2.95*	African	Indian	-1.46
		African	European	-3.91
		Indian	European	-2.46
Sit and reach, cm	16.50**	African	Indian	4.07**
		African	European	1.21
		Indian	European	-2.86

* $p<0.05$ ** $p<0.01$

[a]Signs for the dash and shuttle run are inverted.

Table 25. (continued)

Dependent variable	F	Scheffé post hoc race differences Race	Race	MD
Sit-ups, #/30 sec	0.11	African	Indian	0.10
		African	European	-0.46
		Indian	European	-0.55
Time in sedentary activities, hours				
Television	6.18**	African	Indian	-0.38
		African	European	0.73
		Indian	European	1.12**
Commuting	135.90**	African	Indian	0.87**
		African	European	0.78**
		Indian	European	-0.09
Computer Games	3.54*	African	Indian	-0.51*
		African	European	0.05
		Indian	European	0.56
Estimated energy expenditure 3-day mean, hours				
Sedentary	18.01**	African	Indian	-0.85**
		African	European	0.11
		Indian	European	0.96**
Light	9.27**	African	Indian	0.46**
		African	European	-0.16
		Indian	European	-0.62**
MVPA	8.98**	African	Indian	0.39**
		African	European	0.03
		Indian	European	-0.35
Estimated energy expenditure 3-day mean (kcal/day)				
Sedentary	0.51	African	Indian	3.06
		African	European	34.17
		Indian	European	31.12
Light	4.52**	African	Indian	46.41**
		African	European	15.68
		Indian	European	-30.72
MVPA	9.41**	African	Indian	89.36**
		African	European	9.55
		Indian	European	-79.81*
Total	8.01**	African	Indian	138.83**
		African	European	59.41
		Indian	European	-79.41
Energy expenditure, 3-day mean (kcal/kg/day)				
Sedentary	3.10*	African	Indian	-0.37
		African	European	0.67
		Indian	European	1.04*
Light	4.80**	African	Indian	1.26**
		African	European	0.17
		Indian	European	-1.09
MVPA	8.87**	African	Indian	2.67**
		African	European	0.23
		Indian	European	-2.44*
Total	13.97**	African	Indian	3.56**
		African	European	1.06
		Indian	European	-2.50*
PAQ-C score	0.15	African	Indian	-0.04
		African	European	0.00
		Indian	European	0.03

* p<0.05 ** p<0.01

The sitting height/stature ratios indicate proportionally shorter legs in European boys, or conversely, proportionally longer legs in Indian boys, but African and Indian boys do not differ in relative leg length. Racial differences in subcutaneous fat are limited to the trunk skinfolds. The sum of trunk and total skinfolds are significantly thicker in Indian than African boys. Indian boys also have higher TER, indicating that proportionally more subcutaneous fat is accumulated on the trunk than on the extremities compared to African and European boys. In contrast, skeletal (biacromial and bicristal) breadths tend to be larger in European boys than in African and Indian boys, who do not differ in these variables. Europeans have less variation in the bicristal and biacromial breadths than in Africans and Indians. The biacromial/bicristal ratio is significantly greater in European than African or Indian boys, indicating proportionately larger shoulders relative to the hips.

The fitness variables show no consistent patterns of racial variation. Indian boys are slower than African boys on the dash. European boys perform better on the distance run and push-ups than African and Indian boys. African boys are more flexible on the sit and reach than Indian boys.

Though significant, estimated time spent in activities of different intensities differs slightly among race groups. Indian boys spend slightly more time in sedentary and light activities than African and European boys. Indian boys engage in less MVPA and spend more time playing computer games and watching television than African boys. African boys have higher light, MVPA and total estimated energy expenditure (kcal/day and kcal/kg/day) than Indian boys, and spend more time commuting to school than

Indian and European boys. The estimated energy expenditure of European boys does not differ significantly from African or Indian boys.

Within race descriptive statistics

The means, standard deviations, and medians (where appropriate) for all variables for African and Indian boys are presented by SES in Tables 26 and 27, respectively. The tables also include results of the ANOVA comparing higher and lower SES boys within each race group. A comparison of European and higher SES African and Indian boys is shown in Table 28. Between group differences of higher SES boys for all significant ANOVAs were tested with the Scheffé Post Hoc test (Table 29).

African boys from higher SES families are taller and heavier, have absolutely longer legs, thicker skinfolds, larger limb and estimated arm muscle circumferences, and larger bicondylar and biepicondylar breadths compared to African boys from lower SES families (Table 26). There are no significant differences in fitness, except for absolute grip strength, which is greater in higher SES boys. The SES-related difference in grip strength is not significant when expressed in per kilogram body mass. Time spent in sedentary, light, and MVPA activities; in television viewing and computer games; and in commuting to school does not differ between SES groups of African boys. In terms of estimated absolute energy expenditure, higher SES African boys tend to expend more energy. This is a function of their larger body mass because there are no SES differences in estimated energy expenditure per unit mass.

In contrast to African boys, SES differences in Indian boys are relatively few (Table 27). Higher SES Indian boys have larger arm and calf circumferences (related to

Table 26. Descriptive statistics for African boys by SES.

	Lower SES				Higher SES				
	N	M	SD	Md	N	M	SD	Md	F
Age, yrs	101	10.5	0.3		108	10.6	0.3		1.59
Mass, kg	101	31.0	5.0	29.9	108	34.1	6.5	33.3	15.10**
Stature, cm	101	136.4	5.8		108	139.2	6.7	140.1	10.08**
BMI, kg/m^2	101	16.6	2.2	16.2	108	17.6	2.8		7.31**
Sitting height, cm	101	69.0	3.4		108	69.8	3.9		2.76
Leg length, cm	101	67.5	4.5		108	69.4	4.8		8.56**
Sit ht/Stat, %	101	50.6	2.0		108	50.2	2.1		1.90
Skinfolds, mm									
Biceps	101	5.8	3.0	5.0	108	7.4	4.2	5.6	9.40**
Triceps	101	10.9	5.3	9.5	108	12.8	5.7	10.8	5.97**
Subscapular	101	7.7	4.2	6.4	108	9.6	6.4	7.0	6.62**
Suprailiac	101	5.8	3.6	4.9	108	7.9	5.2	5.8	10.35**
Abdominal	101	9.5	6.1	7.4	108	12.0	7.5	8.8	6.52**
Σ of Trunk	101	17.2	10.0	14.3	108	21.6	13.4	16.2	6.92**
Σ of Extremity	101	16.8	8.0	14.2	108	20.2	9.6	15.8	7.77**
Σ of 5	101	39.9	21.1	34.6	108	49.7	26.9	37.8	8.29**
TER, mm/mm		1.02	0.21	1.01	108	1.05	0.25	1.06	0.93
Circumference, cm									
Relaxed arm	101	19.7	2.1	19.3	108	0.6	2.7	20.2	7.87**
Calf	101	27.2	2.2	27.0	108	28.2	2.8	27.7	8.57**
Arm muscle area, cm^2	101	28.4	6.4	27.4	108	30.7	9.1	29.0	4.63*
Breadth, cm									
Biacromial	101	28.4	1.9		108	28.9	2.7		1.97
Bicristal	101	19.6	2.0		108	19.6	2.2		0.11
Biepicondylar	101	5.5	0.4		108	5.6	0.4		4.94*
Bicondylar	101	8.0	0.5		108	8.2	0.6		6.57**
Bicr/Biac, %	101	69.0	5.5		108	67.9	4.5		2.98*

* $p<0.05$, with F ratios >3.66
** $p<0.01$, with F ratios >5.97

Table 26. (continued)

	Lower SES			Higher SES			
	N	Mean	SD	N	Mean	SD	F
Physical fitness							
Dash, sec	97	9.4	1.3	104	9.5	1.2	0.58
Grip, kg	97	18.6	3.1	108	19.9	3.9	6.53**
Grip, kg/kg mass	97	0.6	0.1	108	0.6	0.1	1.52
Shuttle run, sec	97	23.0	2.4	106	23.0	2.5	0.04
Standing long jump, cm	97	149.9	19.9	103	151.3	23.0	0.20
9 - minute run, m	97	1612.0	314.3	108	1627.6	397.9	0.10
Push-ups, #/30 sec	97	24.1	7.6	107	23.4	8.9	0.37
Sit and reach, cm	97	28.4	5.6	107	27.4	5.8	1.59
Sit-ups, #/30 sec	97	16.5	5.2	106	16.3	5.6	0.10
Time in sedentary activities, 3 day mean, hours							
Television	90	2.2	1.3	97	2.2	1.3	0.12
Commute	90	1.4	0.8	97	1.5	0.8	0.55
Computer Games	90	0.1	0.4	97	0.1	0.3	0.45
Energy expenditure, 3-day mean, hours							
Sedentary	90	19.6	1.4	97	19.8	1.2	2.27
Light	90	2.7	1.0	97	2.7	0.9	0.62
MVPA	90	1.7	0.7	97	1.5	0.9	2.85
Energy expenditure, 3-day mean (kcal/day)							
Sedentary	90	670.7	128.2	97	762.7	166.1	16.93**
Light	90	263.1	116.6	97	285.7	128.0	1.52
MVPA	90	313.7	156.1	97	298.4	191.7	0.34
Total	90	1247.5	236.9	97	1346.8	295.3	6.07**
Energy expenditure, 3-day mean (kcal/kg/day)							
Sedentary	90	21.7	2.1	97	22.2	1.9	0.06
Light	90	8.5	3.4	97	8.3	3.3	0.77
MVPA	90	10.3	5.2	97	8.9	5.8	3.66*
Total	90	40.5	5.5	97	39.5	5.6	1.49
PAQ-C score	98	2.7	0.4	97	2.8	0.5	1.2

* $p<0.05$, with F ratios >3.66

** $p<0.01$, with F ratios >5.97

Table 27. Descriptive statistics for Indian boys by SES.

	Lower SES (n=33-38)				Higher SES (n=86-99)				
	N	M	SD	Md	N	M	SD	Md	F
Age, yrs	38	10.6	0.3		101	10.5	0.3		2.74
Mass, kg	38	30.5	7.0	29.3	101	33.0	7.8	31.3	3.02
Stature, cm	38	137.6	7.0		101	139.5	6.8		2.05
BMI, kg/m^2	38	15.9	2.5	15.2	101	16.8	3.0	16.1	2.72
Sitting height, cm	38	69.0	3.8		101	69.9	3.4		1.50
Leg length, cm	38	68.6	4.7		101	69.6	5.1		1.21
Sit Ht/Stat, %	38	50.2	1.8		101	50.1	1.9		0.03
Skinfolds, mm									
Biceps	38	6.9	3.7	5.2	101	7.5	4.3	6.2	0.68
Triceps	38	11.5	4.9	9.8	101	13.5	6.1	12.2	3.16
Subscapular	38	8.7	5.4	6.5	101	10.6	8.0	7.6	1.88
Suprailiac	38	8.0	6.2	5.6	101	9.1	6.6	6.6	0.81
Abdominal	38	12.3	7.9	8.9	101	14.5	9.7	11.2	1.47
Σ Trunk	38	21.0	12.8	15.6	101	25.6	17.9	18.8	2.12
Σ Extremity	38	18.4	8.4	14.6	101	21.3	10.4	18.3	2.41
Σ 5	38	47.3	26.7	36.7	101	56.2	33.8	45.2	2.12
TER, mm/mm		1.10	0.22	1.14	101	1.14	0.30	1.13	0.67
Circumference, cm									
Relaxed arm	38	19.3	2.7	18.7	101	20.5	3.0	20.0	4.10*
Calf	38	26.3	2.8	26.2	101	27.5	3.0	27.0	4.77*
Arm muscle area, cm^2	38	31.3	8.5	28.6	101	31.6	9.4	29.3	0.03
Breadth, cm									
Biacromial	38	28.1	2.4		101	28.8	2.3		3.12
Bicristal	38	19.8	2.2		101	19.8	2.1		0.00
Biepicondylar	38	5.5	0.4		101	5.5	0.4		0.39
Bicondylar	38	8.1	0.5		101	8.1	0.5		0.58
Bicr/biac, %	38	71.0	6.3		101	69.0	6.0		3.15

* $p<0.05$, with F ratios >4.10
** $p<0.01$

Table 27. (continued)

	Lower SES			Higher SES			
	N	M	SD	N	M	SD	F
Physical fitness							
Dash, sec	38	9.6	0.8	98	9.8	1.3	0.54
Grip, kg	38	17.5	3.0	98	18.9	3.4	4.46*
Grip, kg/kg mass	38	0.59	0.09	98	0.59	0.11	0.00
Shuttle run, sec	38	22.4	2.7	98	23.5	2.8	4.42*
Standing long jump, cm	38	147.7	20.5	98	150.4	22.7	0.41
9-minute run, m	38	1665.0	344.0	98	1510.8	328.8	5.87*
Push-ups, #/30 sec	38	23.9	8.6	98	25.8	8.2	1.38
Sit and reach, cm	38	23.6	5.7	98	24.2	6.0	0.30
Sit-ups, #/30 sec	38	17.7	6.9	98	15.9	5.4	2.70
Time in sedentary activities, 3 day mean, hours							
Television	33	2.2	1.4	88	2.6	1.6	1.47
Commuting	33	0.2	0.3	88	0.2	0.4	0.04
Computer Games	33	0.2	0.5	88	0.2	0.6	0.09
Energy expenditure 3-day mean, hours							
Sedentary	33	20.3	1.1	88	20.6	1.1	1.01
Light	33	2.4	0.9	88	2.3	0.9	0.95
MVPA	33	1.2	0.7	88	1.2	0.7	0.05
Energy expenditure, 3-day mean (kcal/day)							
Sedentary	33	674.3	151.3	88	754.7	205.1	4.20*
Light	33	236.7	116.4	88	235.3	139.6	0.00
MVPA	33	206.6	143.5	88	223.9	155.9	0.31
Total	33	1117.6	278.4	88	1213.9	341.6	2.10
Energy expenditure, 3-day mean (kcal/kg/day)							
Sedentary	33	22.2	2.0	88	22.3	1.8	0.06
Light	33	7.7	3.2	88	6.9	3.4	1.32
MVPA	33	6.9	4.0	88	6.8	4.7	0.00
Total	33	36.8	4.3	88	36.1	5.4	0.49
PAQ-C score	38	3.0	0.5	98	2.8	0.7	1.92

* $p<0.05$, with F ratios >4.10
** $p<0.01$

slightly larger limb skinfold thicknesses, respectively) and are stronger in grip strength compared to Indian boys from lower SES families. Lower SES Indian boys perform better ($p < 0.05$) in the 9 minute and shuttle runs, but higher SES Indian boys expend more energy in sedentary activities. The higher estimated energy expenditure (kcal/day) of higher SES boys apparently reflects their larger body mass since estimated energy expenditure relative to body mass does not differ significantly. All other variables do not differ significantly between higher and lower SES Indian boys.

Anthropometry, physical fitness and estimated energy expenditure of higher SES African, Indian and European boys are shown in Tables 28 and 29. Race differences in the sitting height/stature and bicristal/biacromial ratios, and bicristal breadth are significant. European boys have proportionally longer trunks relative to their legs than higher SES African and Indian boys. Higher SES African and Indian boys have proportionally broader shoulder relative to the hips than European boys. The estimated subcutaneous adipose tissue of higher SES African, Indian and European boys do not differ significantly.

Performances in the distance run, push-ups and sit and reach are significantly different among higher SES African, Indian and European boys. European boys run a greater distance in nine minutes and complete more push-ups in 30 seconds than higher SES African boys. European boys also have better distance run performances than higher SES Indian boys. There are no significant differences in the distance run and push-ups performances of higher SES African and Indian boys, or the push-ups performance of European and higher SES Indian boys. Higher SES African boys have

Table 28. Descriptive statistics for higher SES African, Indian and European boys.

	African				Indian				European				
	N	M	SD	Md	N	M	SD	Md	N	M	SD	Md	F
Age, yrs	108	10.6	0.3		101	10.5	0.3		41	10.5	0.4		0.95
Mass, kg	108	34.1	6.5	33.3	101	33.6	8.6	31.3	41	33.7	5.7	33.3	0.16
Stature, cm	108	139.2	6.6		101	139.5	6.8		41	139.2	6.4		0.07
BMI, kg/m^2	108	17.6	2.8	16.9	101	16.8	3.0	16.1	41	17.4	2.6	17.4	1.64
Leg length, cm	108	69.4	4.8		101	69.6	5.1		41	67.5	4.2		1.45
Sitting height, cm	108	69.8	3.9		101	69.9	3.5		41	71.8	2.9		4.71**
SH/ST, %	108	50.2	2.1		101	50.1	1.9		41	51.6	1.2		9.61**
Skinfolds, mm													
Biceps	108	7.4	4.2	5.6	101	7.7	4.5	6.2	41	6.6	3.6	5.4	0.82
Triceps	108	12.8	5.7	10.8	101	13.7	6.3	12.2	41	13.2	5.9	11.2	0.54
Subscapular	108	9.6	6.4	7.0	101	10.9	8.4	7.7	41	8.0	5.1	6.3	2.54
Suprailiac	108	7.9	5.2	5.8	101	9.3	7.0	6.6	41	7.5	5.2	5.6	2.05
Abdominal	108	12.0	7.5	8.8	101	14.7	10.0	11.2	41	11.7	7.2	9.7	3.01
Σ of Trunk	108	21.6	13.4	16.2	101	25.6	17.9	18.8	41	19.7	11.8	15.9	2.90
Σ of Extremity	108	20.2	9.6	15.8	101	21.3	10.4	18.3	41	19.9	9.3	16.7	0.47
Σ of 5	108	49.7	26.9	37.8	101	56.2	33.8	45.2	41	47.0	25.3	38.8	1.92
TER, mm/mm	108	1.05	0.25	1.06	101	1.15	0.30	1.13	41	0.98	0.23	0.95	3.00
Circumference, cm													
Relaxed arm	108	20.6	2.7	20.2	101	20.6	3.2	20.0	41	21.0	2.5	21.0	0.24
Calf	108	28.2	2.8	27.7	101	27.6	3.1	27.1	41	28.1	2.71	28.3	1.91
Arm muscle area, cm^2	108	30.7	9.1	28.8	101	31.9	9.9	29.4	41	30.9	7.0	30.7	0.42
Breadth, cm													
Biacromial	108	28.9	2.7		101	28.9	2.3		41	29.8	1.3		2.64
Bicristal	108	19.6	2.2		101	19.8	2.1		41	21.4	1.3		12.55**
Biepicondylar	108	5.6	0.4		101	5.6	0.4		41	5.6	0.4		0.53
Bicondylar	108	8.2	0.6		101	8.1	0.6		41	8.3	0.5		2.07
Bicr/biac, %	108	67.9	4.7		101	68.8	5.5		41	72.0	3.6		10.51**

* $p<0.05$

** $p<0.01$

Table 28. (continued)

	African			Indian			European			
	N	M	SD	N	M	SD	N	M	SD	F
Physical fitness										
Dash, sec	104	9.5	1.1	101	9.8	1.3	41	9.4	1.0	2.68
Grip, kg	108	19.9	3.8	98	19.0	3.5	41	19.3	3.0	1.90
Grip, kg/kg mass	108	0.6	0.1	98	0.6	0.1	41	0.6	0.1	0.02
Shuttle run, sec	106	23.0	2.5	101	23.5	2.7	41	22.5	2.2	2.19
Standing long jump, cm	103	151.1	22.9	101	150.6	22.5	41	157.7	21.9	1.61
9-minute run, m	108	1621.0	399.2	101	1512.7	326.8	41	1875.4	471.6	12.99**
Push-ups, #/30 sec	107	23.4	8.8	99	25.8	8.2	41	28.0	8.0	4.78**
Sit and reach, cm	107	27.3	5.8	99	24.1	6.0	41	25.7	5.4	7.55**
Sit-ups, #/30 sec	106	16.3	5.5	102	16.0	5.5	41	17.2	5.5	0.68
Time in sedentary activities, 3-day mean, hours										
Television	94	2.5	1.4	88	3.1	1.8	28	1.8	1.1	8.04**
Commuting	94	2.7	1.4	88	0.2	0.3	28	0.3	0.46	101.10**
Computer games	94	1.2	0.6	88	3.5	1.9	28	2.6	1.90	5.79**
Energy expenditure 3-day mean, hours										
Sedentary	94	20.0	1.2	88	20.6	1.1	28	19.7	1.3	10.09**
Light	94	2.7	0.9	88	2.2	0.9	28	2.9	1.0	8.58**
MVPA	94	1.5	0.9	88	1.2	0.7	28	1.5	0.8	4.01*
Energy expenditure 3-day mean (kcal/day)										
Sedentary	94	762.7	166.1	88	754.7	205.1	28	692.6	144.8	1.67
Light	94	285.7	128.0	88	235.3	139.6	28	269.4	111.6	3.40*
MVPA	94	298.4	191.7	88	223.9	155.9	28	307.8	204.9	4.69**
Total	94	1346.8	295.3	88	1213.9	341.6	28	1269.8	263.7	4.14*
Energy expenditure 3-day mean (kcal/kg/day)										
Sedentary	94	22.2	1.9	88	22.3	1.8	28	21.3	2.5	3.36*
Light	94	8.3	3.3	88	6.9	3.4	28	8.4	3.3	4.49**
MVPA	94	8.9	5.8	88	6.8	4.7	28	9.6	6.1	4.70**
Total	94	39.5	5.6	88	36.1	5.4	28	39.2	6.6	8.90**
PAQ-C score	108	2.8	0.5	101	2.8	0.7	41	2.8	0.5	0.15

* $p<0.05$

** $p<0.01$

Table 29. Scheffé post hoc tests of mean differences (MD) between races for variables showing a significant F ratio among higher SES boys.

	Scheffé post hoc race differences		
Dependent variable	Race	Race	MD
Growth Status			
Sitting height/ stature ratio, %	African	Indian	0.05
	African	European	-1.39**
	Indian	European	-1.42**
Bicristal	African	Indian	-0.02
	African	European	-1.82**
	Indian	European	-1.79**
Bicristal/biacromial ratio, %	African	Indian	-1.68
	African	European	-5.06**
	Indian	European	-3.38*
Physical Fitness			
Grip, kg	African	Indian	1.19*
	African	European	0.54
	Indian	European	-0.64
9-minute run, m	African	Indian	91.32
	African	European	-260.76**
	Indian	European	-352.08**
Push-ups, #/30 sec	African	Indian	-2.96*
	African	European	-5.47**
	Indian	European	-2.52
Sit and reach, cm	African	Indian	2.90**
	African	European	1.57
	Indian	European	-1.33
Time in sedentary activities, hours			
Television	African	Indian	-0.60*
	African	European	0.68
	Indian	European	1.28**
Commuting	African	Indian	0.88**
	African	European	0.78**
	Indian	European	-0.11
Computer Games	African	Indian	-0.79**
	African	European	-0.03
	Indian	European	0.82
Estimated energy expenditure 3-day mean, hours			
Sedentary	African	Indian	-0.68**
	African	European	0.32
	Indian	European	1.00**
Light	African	Indian	0.40
	African	European	-0.32
	Indian	European	-0.72**
Estimated energy expenditure 3-day mean (kcal/day)			
Total	African	Indian	136.40*
	African	European	83.57
	Indian	European	-52.83
Energy expenditure, 3-day mean (kcal/kg/day)			
Total	African	Indian	3.23*
	African	European	0.40
	Indian	European	-2.83

* $p<0.05$ ** $p<0.01$

greater flexibility of the lower back on the sit and reach test than higher SES Indian boys; higher SES Indian and European boys, however, do not differ significantly.

There are significant race differences among higher SES boys in the time spent in commuting, television viewing and playing computer games. Higher SES African boys spend more time commuting than higher SES Indian and European boys. Higher SES Indian and European boys have similar commutes. Higher SES Indian boys watch more television than African and European boys, who do not differ significantly from each other. Higher SES Indian boys also play significantly more computer games than higher SES African boys. Higher SES Indian boys spend more time in sedentary activities than higher SES African and European boys and have a higher relative energy expenditure (kcal/kg/day) in sedentary activity than higher SES African boys. European boys spend more time engaged in light activities than higher SES Indian boys. There are no significant differences in the estimated energy expenditure (kcal/day and kcal/kg/day) in light activities among European and higher SES African and Indian boys. Higher SES African boys have higher mean daily total estimated energy expenditure (kcal/day and kcal/kg/day) than higher SES Indian boys.

Means, standard deviations and medians (where appropriate), ANOVAs and Scheffé post hoc tests of all variables for African, Indian and European boys by nutritional status are presented in Tables 30-31, 32-33, and 34, respectively. These are shown separately to reduce the confounding effects of race on nutritional status.

BMI-for-age was used as a proxy for nutritional status. Regardless of race, overweight boys have larger skinfold thicknesses, circumferences and estimated arm muscle areas, and proportionally more subcutaneous fat on the trunk relative to the

Table 30. Descriptive statistics of African boys by nutritional status based on the BMI.

	≤ 15 percentile (BMI-for-Age) Undernourished				15th > NN < 85th (BMI-for-Age) Nutritionally normal				≥ 85th percentile (BMI-for-Age) Overweight				
% of sample	18.3%				68.3%				13.5%				
	N	M	SD	Md	N	M	SD	Md	N	M	SD	Md	F
Age, years	38	10.5	0.3		142	10.5	0.3		28	10.5	0.3		0.55
Mass, kg	38	27.4	3.1	27.0	142	31.8	3.6	31.8	28	43.7	5.2	41.9	88.88**
Stature, cm	38	137.7	6.2		142	137.4	6.5		28	140.2	5.9		1.82
BMI	38	14.4	0.9	14.5	142	16.8	1.1	16.7	28	22.3	2.3	22.2	148.13**
Leg length, cm	38	69.7	4.3		142	68.0	4.7		28	68.9	5.5		0.81
Sitting height, cm	38	68.0	3.4		142	69.4	3.5		28	71.3	4.2		2.62
Sit ht/ Stat,%	38	49.4	1.7		142	50.5	1.9		28	50.9	2.8		1.05
Skinfolds, mm													
Biceps	38	4.4	1.3	4.4	142	6.0	2.8	5.2	28	12.8	3.8	12.9	26.66**
Triceps	38	8.1	2.2	7.9	142	10.9	3.8	9.8	28	22.0	4.9	21.1	56.48**
Subscapular	38	5.5	1.2	5.3	142	7.5	3.4	6.8	28	18.9	6.3	17.2	45.06**
Suprailiac	38	4.3	1.0	4.2	142	5.8	2.3	5.4	28	15.7	6.0	14.6	58.70**
Abdominal	38	6.1	1.5	5.6	142	9.2	3.9	8.5	28	25.0	5.9	24.9	95.02**
Σ of Trunk	38	11.6	2.3	11.4	142	16.8	6.5	15.6	28	43.9	11.7	41.1	82.15**
Σ of Extremity	38	12.5	3.1	12.2	142	16.9	6.2	15.2	28	34.9	8.4	33.7	47.75**
Σ of 5	38	28.4	5.4	27.5	142	39.6	13.5	36.6	28	94.5	24.0	89.6	77.28**
TER, mm/mm	38	0.95	0.19	0.98	142	1.01	0.21	1.02	28	1.28	0.25	1.23	8.56**
Circumference, cm													
Relaxed arm	38	17.9	1.1	18.0	142	19.8	1.5	19.8	28	24.7	2.2	24.6	71.05**
Calf	38	25.6	1.4	26.0	142	27.5	1.7	27.4	28	32.0	2.7	32.1	85.09**
AMA[a], cm^2	38	26.3	7.1	25.7	142	29.3	6.6	28.3	28	35.8	11.6	35.5	20.36**
Breadths, cm													
Biacromial	38	27.7	2.6		142	28.6	2.1		28	30.3	2.6		6.67**
Bicristal	38	17.6	2.2		142	18.6	2.1		28	19.5	3.1		4.17*
Biepicondylar	38	5.4	0.3		142	5.5	0.4		28	5.8	0.3		11.23**
Bicondylar	38	7.8	0.4		142	8.1	0.4		28	8.8	0.5		26.20**
Bicr/Biac, %	38	63.6	5.5		142	65.2	5.7		28	64.1	6.4		0.44

* $p<0.05$ ** $p<0.01$

[a] AMA - arm muscle area

Table 30. (continued)

	≤ 15 percentile (BMI-for-Age) Undernourished			15th > NN < 85th (BMI-for-Age) Nutritionally normal			≥ 85th percentile (BMI-for-Age) Overweight			
	N	M	SD	N	M	SD	N	M	SD	F
Physical fitness										
Dash, sec	38	9.2	1.4	138	9.4	1.2	28	9.6	1.2	1.55
Grip, kg	38	18.0	2.6	138	19.2	3.4	28	21.5	4.6	9.30**
Grip, kg/kg mass	38	0.7	0.1	138	0.6	0.1	28	0.5	0.1	9.11**
Shuttle run, sec	38	22.8	2.3	138	23.0	2.6	28	23.3	2.2	0.89
Standing long jump, cm	38	152.9	21.0	138	149.8	22.1	28	151.5	19.7	0.43
9 - minute run, m	38	1566.2	335.5	138	1661.4	365.9	28	1489.9	326.9	2.34
Push-ups, #/30 sec	38	23.1	7.3	138	24.6	8.4	28	20.4	8.5	1.64
Sit and reach, cm	38	27.3	5.8	138	27.9	5.4	28	28.1	7.0	0.02
Sit-ups, #/30 sec	38	15.2	4.2	138	17.3	5.7	28	13.8	3.7	4.42**
Time in sedentary activities, 3 day mean, hours										
Television	29	2.0	1.1	125	2.3	1.3	24	2.0	1.4	0.09
Commute	29	1.7	0.8	125	1.3	0.8	24	1.4	1.0	0.34
Computer Game	29	0.1	0.2	125	0.1	0.3	24	0.2	0.4	2.32
Energy expenditure 3-day mean, hours										
Sedentary	29	19.8	1.4	125	19.8	1.3	24	19.9	1.1	0.99
Light	29	2.5	0.9	125	2.8	0.9	24	3.0	0.9	0.44
MVPA	29	1.8	0.8	125	1.6	0.8	24	1.3	0.7	1.98
Energy expenditure, 3-day mean (kcal/day)										
Sedentary	29	590.7	80.1	125	704.0	107.4	24	968.1	157.3	48.13**
Light	29	207.8	90.8	125	269.7	110.0	24	388.0	148.3	5.36**
MVPA	29	314.9	135.8	125	296.8	177.7	24	343.2	207.8	0.24
Total	29	1113.4	144.3	125	1270.6	229.0	24	1699.3	201.1	36.46**
Energy expenditure, 3-day mean (kcal/kg/day)										
Sedentary	29	21.7	1.5	125	22.1	2.1	24	21.9	2.2	2.00
Light	29	7.8	3.5	125	8.4	3.3	24	8.9	3.5	0.60
MVPA	29	11.8	5.5	125	9.3	5.6	24	7.9	4.8	1.75
Total	29	41.2	6.0	125	39.9	5.6	24	38.6	4.2	2.10
PAQ-C score	38	2.7	0.3	138	2.8	0.5	28	2.6	0.3	1.06

* p<0.05   ** p<0.01

extremities (higher TER), while undernourished boys have the lowest fatness and estimated arm musculature, proportionally smaller SAT on the trunk relative to the extremities, and the smallest circumferences and breadths. For all significant ANOVAs, the Scheffé post hoc test was used to test specific pairs of means (Tables 31 and 33, for African and Indian boys, respectively).

Skinfold thicknesses, TERs, circumferences, estimated arm muscle area, and skeletal breadths of overweight boys are significantly larger than undernourished and nutritionally normal African boys. Nutritionally normal boys also have greater sum of skinfolds, circumferences and estimated arm muscle area compared to undernourished boys.

Overweight African boys have significantly greater absolute and relative grip strength than undernourished and nutritionally normal boys. But, when grip strength is expressed relative to body weight, both undernourished and nutritionally normal African boys have greater grip strength per kilogram mass than overweight African boys. Grip strength relative to body mass (kg/kg) of undernourished and nutritionally normal African boys do not differ significantly. Nutritionally normal African boys have greater absolute grip strength compared to undernourished African boys.

Overweight African boys have significantly greater sedentary, light and mean daily total estimated energy expenditure (kcal/day) compared to undernourished and nutritionally normal African boys, and nutritionally normal African boys have greater estimated energy expenditure in sedentary and mean daily total estimated energy expenditure (kcal/day) than undernourished African boys. The estimated energy expenditure (kcal/day) differences between overweight, nutritionally normal and

Table 31. Scheffé post hoc tests of mean differences (MD) between nutritional status of African boys for variables showing a significant F ratio.

Dependent variable	Nutritional Status[a]		MD
Mass, kg	UN	NN	-4.65**
	UN	OW	-18.37**
	NN	OW	-13.72**
BMI, kg/m^2	UN	NN	-2.35**
	UN	OW	-8.47**
	NN	OW	-6.12**
Skinfolds, mm			
Biceps	UN	NN	-2.01
	UN	OW	-8.58**
	NN	OW	-6.57**
Triceps	UN	NN	-3.80**
	UN	OW	-15.35**
	NN	OW	-11.56**
Subscapular	UN	NN	-2.43
	UN	OW	-13.94**
	NN	OW	-11.50**
Suprailiac	UN	NN	-1.86
	UN	OW	-12.78**
	NN	OW	-10.93**
Abdominal	UN	NN	-3.42**
	UN	OW	-19.61**
	NN	OW	-16.19**
Σ of Trunk	UN	NN	-5.85*
	UN	OW	-33.55**
	NN	OW	-27.70**
Σ of Extremity	UN	NN	-5.81**
	UN	OW	-23.94**
	NN	OW	-18.13**
Σ of 5	UN	NN	-13.51**
	UN	OW	-70.27**
	NN	OW	-56.75**
Circumferences, cm			
Relaxed arm	UN	NN	-2.26**
	UN	OW	-7.25**
	NN	OW	-4.99**
Calf	UN	NN	-2.22**
	UN	OW	-7.74**
	NN	OW	-5.52**
Estimated muscle area, cm^2			
Arm	UN	NN	-5.02*
	UN	OW	-16.86**
	NN	OW	-11.84**

[a] UN: undernourished, NN: nutritionally normal, and OW: overweight.

* $p<0.05$

** $p<0.01$

Table 31. (continued)

Dependent variable	Nutritional	Status	MD
Breadth, cm			
Biacromial	UN	NN	-0.81
	UN	OW	-2.76**
	NN	OW	-1.94**
Bicristal	UN	NN	-0.93
	UN	OW	-2.27*
	NN	OW	-1.34
Biepicondylar	UN	NN	-0.19
	UN	OW	-0.65**
	NN	OW	-0.46**
Bicondylar	UN	NN	-0.20
	UN	OW	-1.07**
	NN	OW	-0.87**
Physical Fitness			
Grip, kg	UN	NN	-2.84*
	UN	OW	-5.82**
	NN	OW	-2.99*
Grip, kg/kg mass	UN	NN	0.00
	UN	OW	0.12**
	NN	OW	0.12**
Sit-ups, #/30 sec	UN	NN	-2.76
	UN	OW	1.81
	NN	OW	4.58*
Estimated energy expenditure 3-day mean (kcal/day)			
Sedentary	UN	NN	-135.20**
	UN	OW	-420.50**
	NN	OW	-285.30**
Light	UN	NN	-15.05
	UN	OW	-116.32*
	NN	OW	-101.27**
Total	UN	NN	-153.33**
	UN	OW	-574.42**
	NN	OW	-421.09**

* $p<0.05$
** $p<0.01$

undernourished African boys are related to body size since estimated energy expenditure per kilogram body mass do not differ significantly among African boys from different nutritional status groups.

Overweight Indian boys are significantly taller, heavier and have longer trunks than nutritionally normal and undernourished Indian boys. Nutritionally normal Indian boys are heavier and have longer trunks than undernourished Indian boys. Overweight Indian boys have significantly larger skinfold thicknesses, TER, circumferences and breadths (biepicondylar and bicondylar) compared to nutritionally normal or undernourished Indian boys (Tables 32 and 33). Additionally, overweight Indian boys have significantly greater TERs than undernourished and nutritionally normal boys, indicating that overweight boys have a larger accumulation of SAT on the trunk relative to their arms compared to undernourished and nutritionally normal Indian boys. Overweight Indian are have broader shoulders and hips compared to nutritionally normal boys, but do not differ in the bicristal/biacromial ratio. Nutritionally normal Indian boys have thicker skinfolds and larger circumferences than undernourished Indian boys.

Overweight Indian boys are significantly slower in the dash than nutritionally normal boys. Overweight Indian boys, on the other hand, have greater absolute grip strength (kgs) than undernourished or nutritionally normal boys, and nutritionally normal Indian boys have greater grip strength (kg) than undernourished boys. This, however, is factor of their larger body size since both nutritionally normal and undernourished Indian boys have greater grip strength per unit body mass compared to overweight Indian boys, and undernourished and nutritionally normal boys do not differ in grip strength per unit

Table 32. Descriptive statistics of Indian boys by nutritional status based on the BMI.

	≤ 15 percentile (BMI-for-Age) Undernourished				>15th > NN < 85th (BMI-for-Age) Nutritionally normal				≥ 85th percentile (BMI-for-Age) Overweight				
% of the sample	36.5%				47.4%				16.1%				
	N	M	SD	Md	N	M	SD	Md	N	M	SD	Md	F
Age	50	10.5	0.3		65	10.5	0.3		22	10.6	0.3		
Mass, kg	50	26.5	3.0	26.2	65	32.2	3.9	31.7	22	45.9	6.0	44.9	89.98**
Stature, cm	50	136.7	6.8		65	139.0	6.3		22	144.1	6.3		10.00**
BMI, kg/m^2	50	14.1	0.7	14.3	65	16.6	1.1	16.2	22	22.1	2.0	21.7	166.08**
Leg length, cm	50	68.6	5.0		65	69.2	4.5		22	71.4	5.8		1.02
Sitting height, cm	50	68.1	3.5		65	69.8	3.2		22	72.7	2.5		15.83**
Sit ht/ Stat,%	50	49.9	2.0		65	50.2	1.6		22	50.5	2.3		1.19
Skinfolds, mm	50				65				22				
Biceps	50	4.9	1.5	4.8	65	6.9	3.0	6.2	22	14.1	3.9	14.1	66.26**
Triceps	50	9.3	3.4	8.5	65	12.7	4.1	12.2	22	22.2	4.2	21.9	47.29**
Subscapular	50	6.2	1.5	6.0	65	8.5	3.3	7.7	22	23.3	9.4	21.7	53.23**
Suprailiac	50	5.0	1.6	5.0	65	7.8	4.3	6.6	22	19.9	6.8	21.7	42.33**
Abdominal	50	7.7	3.0	7.3	65	13.1	6.1	11.6	22	30.2	7.2	29.1	63.29**
Σ of Trunk	50	13.9	3.8	14.2	65	21.6	8.9	19.1	22	53.5	15.4	52.8	71.39**
Σ of Extremity	50	14.2	4.5	13.1	65	19.6	6.6	18.5	22	36.3	7.5	37.5	62.87**
Σ of 5	50	33.2	8.5	32.6	65	49.0	18.4	43.2	22	109.7	24.8	112.4	75.66**
TER, mm/mm	50	1.01	0.21	1.03	65	1.11	0.23	1.14	22	1.47	0.30	1.49	9.06**
Circumference, cm													
Relaxed arm	50	17.7	1.2		65	20.4	1.7		22	25.1	1.9		81.48**
Calf	50	24.8	1.7		65	27.4	1.6		22	31.9	2.7		40.21**
AMA, cm^2	50	31.3	10.6		65	30.7	8.6		22	34.4	6.9		1.31
Breadths, cm	50				65				22				
Biacromial	50	27.8	2.1		65	28.7	2.2		22	30.1	2.5		3.81*
Bicristal	50	18.2	1.9		65	18.9	2.3		22	20.3	2.1		5.05**
Biepicondylar	50	5.3	0.3		65	5.5	0.3		22	6.0	0.3		18.03**
Bicondylar	50	7.8	0.4		65	8.2	0.4		22	8.7	0.5		17.28**
Bicr/Biac, %	50	65.5	5.9		65	65.7	6.3		22	67.6	5.9		0.93

* $p<0.05$ ** $p<0.01$

Table 32. (continued)

	≤ 15 percentile (BMI-for-Age) Undernourished			>15th > NN < 85th (BMI-for-Age) Nutritionally normal			≥ 85th percentile (BMI-for-Age) Overweight			
	N	Mean	SD	N	Mean	SD	N	Mean	SD	F
Physical fitness										
Dash, sec	45	9.7	1.1	65	9.5	1.1	22	10.6	1.4	3.94*
Grip, kg	45	16.8	2.7	65	19.0	3.5	22	21.2	2.2	12.04**
Grip, kg/kg mass	45	0.6	0.1	65	0.6	0.1	22	0.5	0.1	22.34**
Shuttle run, sec	45	22.7	2.0	65	23.2	3.2	22	24.1	2.8	2.99
Long jump, cm	45	146.7	21.5	65	154.0	17.2	22	143.5	32.4	2.65
9 - minute run, m	45	1609.7	304.3	65	1560.9	358.6	22	1408.9	325.5	1.63
Push-ups, #/30 sec	45	25.0	7.3	65	26.2	8.9	22	22.9	8.6	1.24
Sit and reach, cm	45	23.1	5.1	65	25.4	6.2	22	21.8	6.1	0.35
Sit-ups, #/30 sec	45	17.0	5.2	65	17.3	5.7	22	12.2	6.3	4.27*
Time in sedentary activities, 3 day mean, hours										
Television	45	2.6	1.6	56	2.1	1.3	22	3.1	2.0	0.88
Commute	45	0.2	0.1	56	0.2	0.4	22	0.2	0.3	0.86
Computer Game	45	0.2	0.5	56	0.3	0.7	22	0.2	0.3	0.05
Energy Expenditure 3-day mean, hours										
Sedentary	45	20.6	1.1	56	20.4	1.0	22	20.5	1.5	1.78
Light	45	2.3	1.0	56	2.3	0.8	22	2.3	1.2	0.26
MVPA	45	1.1	0.6	56	1.3	0.6	22	1.1	0.9	2.15
Energy expenditure, 3-day mean (kcal/day)										
Sedentary	45	592.7	84.9	56	719.0	103.2	22	1018.9	176.6	65.13**
Light	45	185.2	89.1	56	230.1	100.0	22	339.2	187.8	6.61**
MVPA	45	178.2	128.5	56	236.6	142.1	22	253.2	209.5	4.42*
Total	45	956.1	162.3	56	1185.7	217.8	22	1611.3	298.5	39.68**
Energy expenditure, 3-day mean (kcal/kg/day)										
Sedentary	45	22.3	1.9	56	22.4	1.8	22	22.1	2.0	0.12
Light	45	7.0	3.2	56	7.2	3.0	22	7.5	4.4	0.76
MVPA	45	6.8	4.6	56	7.4	4.3	22	5.6	4.8	2.98
Total	45	36.1	4.9	56	36.8	5.1	22	35.1	5.6	3.51*
PAQ-C score	50	2.7	0.6	65	2.9	0.7	22	3.0	0.6	0.52

* $p<0.05$ ** $p<0.01$

Table 33. Scheffé post hoc tests of mean differences (MD) between nutritional status of Indian boys for variables showing a significant F ratio.

Dependent variable	Nutritional status[a]		MD
Mass, kg	UN	NN	-6.20**
	UN	OW	-20.91**
	NN	OW	-14.71**
Stature, cm	UN	NN	-2.26
	UN	OW	-7.43**
	NN	OW	-5.17**
BMI, kg/m^2	UN	NN	-2.53**
	UN	OW	-8.46**
	NN	OW	-5.94**
Sitting height, cm	UN	NN	-1.68*
	UN	OW	-4.64**
	NN	OW	-2.96**
Skinfolds, mm			
Biceps	UN	NN	-2.36**
	UN	OW	-9.55**
	NN	OW	-7.19**
Triceps	UN	NN	-3.23**
	UN	OW	-13.67**
	NN	OW	-10.44**
Subscapular	UN	NN	-2.19
	UN	OW	-15.34**
	NN	OW	-13.16**
Suprailiac	UN	NN	-3.46*
	UN	OW	-15.68**
	NN	OW	-12.22**
Abdominal	UN	NN	-6.61**
	UN	OW	-23.32**
	NN	OW	-16.70**
Σ of Trunk	UN	NN	-8.80**
	UN	OW	-38.66**
	NN	OW	-29.86**
Σ of Extremity	UN	NN	-5.60**
	UN	OW	-23.23**
	NN	OW	-17.63**
Σ of 5	UN	NN	-17.85**
	UN	OW	-77.57**
	NN	OW	-59.71**
TER, mm/mm	UN	NN	-0.14
	UN	OW	-0.41**
	NN	OW	-0.27**
Circumferences, cm			
Relaxed arm	UN	NN	-2.66**
	UN	OW	-7.71**
	NN	OW	-5.06**
Calf	UN	NN	-2.54**
	UN	OW	-6.63**
	NN	OW	-4.09**

[a] UN: undernourished, NN: nutritionally normal, and OW: overweight.

* $p<0.05$ ** $p<0.01$

Table 33. (continued)

Dependent variable	Nutritional status		MD
Breadth, cm			
Biacromial	UN	NN	-1.31
	UN	OW	-2.34*
	NN	OW	-1.02
Bicristal	UN	NN	-1.55*
	UN	OW	-2.46*
	NN	OW	-0.91
Biepicondylar	UN	NN	-0.20
	UN	OW	-0.76**
	NN	OW	-0.56**
Bicondylar	UN	NN	-0.42**
	UN	OW	-0.91**
	NN	OW	-0.49**
Physical Fitness			
Dash, sec	UN	NN	0.30
	UN	OW	0.80
	NN	OW	1.10*
Grip, kg	UN	NN	-3.25**
	UN	OW	-4.26**
	NN	OW	-1.00
Grip, kg/kg mass	UN	NN	0.02
	UN	OW	0.18**
	NN	OW	0.16**
Sit-ups, #/30 sec	UN	NN	0.30
	UN	OW	5.82*
	NN	OW	5.52*
Estimated energy expenditure 3-day mean (kcal/day)			
Sedentary	UN	NN	-131.89**
	UN	OW	-468.92**
	NN	OW	-337.04**
Light	UN	NN	-60.30
	UN	OW	-119.21**
	NN	OW	-58.91
MVPA	UN	NN	-100.61*
	UN	OW	-52.13
	NN	OW	48.47
Total	UN	NN	-292.79**
	UN	OW	-640.27**
	NN	OW	-347.48**
Energy expenditure, 3-day mean (kcal/kg/day)			
Total	UN	NN	-1.94
	UN	OW	2.33
	NN	OW	4.27*

* $p<0.05$ ** $p<0.01$

mass. Nutritionally normal and undernourished Indian boys also complete more sit-ups in 30 seconds than overweight boys.

Overweight Indian boys have greater sedentary and mean daily total estimated energy expenditure (kcal/day) than nutritionally normal and undernourished Indian boys, and nutritionally normal boys have greater estimated mean daily total energy expenditure (kcal/day) than undernourished Indian boys. The higher estimated energy expenditure is due to the larger body size of overweight and nutritionally normal boys, respectively, since there are no significant differences in estimated energy expenditure relative to body mass (kcal/kg/day). However, nutritionally normal Indian boys have a higher mean daily total estimated energy expenditure per unit mass (kcal/kg/day) than overweight Indian boys. The number of underweight (n=6-7) and overweight (n=1-3) European boys are too small for comparisons.

Habitual physical activity

Subjects indicated the number of times that they participated in popular sport and physical activities over the past seven days. The frequency of participation based on participation or non-participation is summarized in Table 34. The eight top ranked physical activities, in order, are soccer, cricket, jogging, bicycling, walking, playing catch, basketball, and hide and seek. The activities with the greatest frequency of participation (6 or more times a week, scored as 5), in order of ranking, are soccer, bicycling, cricket, jogging, walking, roller skating, basketball, and playing catch. Only 37 (11%) boys indicated that they did not participate in soccer in the past seven days, while 153 (44%) participated in soccer six or more times. The least popular activities, in

Table 34. Participation in specific physical activities by frequency of participation in the past seven days for the total sample (n=350).

	Rank		Frequency of participation				
	Mean	Md	None	1 to 2	3 to 4	5 to 6	6 or more
			Rank				
			1	2	3	4	5
Soccer	3.7	4	37	52	49	59	153
Cricket	2.9	3	41	67	52	56	72
Jogging	2.7	3	100	63	81	47	59
Bicycling	2.7	2	126	55	40	48	81
Walk	2.5	2	111	95	51	38	55
Catch	2.2	2	148	83	54	29	36
Basketball	2.2	2	166	68	41	32	42
Hide and seek	2.1	1	175	66	47	35	26
Roller skating	2.0	1	194	60	33	18	45
Softball	1.8	1	212	61	32	18	27
Swim	1.8	1	221	59	16	30	24
Table tennis	1.5	1	243	60	24	11	12
Volleyball	1.5	1	253	46	29	7	15
Dance	1.5	1	267	32	25	6	20
Skateboard	1.5	1	268	33	14	13	22
Aerobics	1.5	1	268	40	12	8	22
Skip	1.4	1	263	52	15	7	12
Hop	1.4	1	280	35	21	4	10
Field Hockey	1.4	1	294	22	10	10	14
Badminton	1.2	1	316	18	6	6	4
Netball	1.1	1	327	14	3	0	6

order, are netball, badminton, field hockey, hopping, aerobics, skipping, skateboarding and dance. Netball, aerobics, dance and skipping are often perceived as feminine activities, while field hockey, badminton and skateboarding are not freely available in the residential areas studied.

Race specific differences in the ten top ranked habitual physical activities are presented in Table 35. The frequency of participation was rated on a 5 point scale with 1: no participation, 2: 1 to 2 times , 3: 3 to 4 times, 4: 5 to 6 times, and 5: more than 6 times a week. The scores (1 to 5) for frequency of participation in each physical activity were used for all statistical calculations. Soccer has the highest frequency of participation among African, Indian and European boys. The top-five ranked habitual physical activities, in rank order, among African boys are soccer, bicycling, cricket, jogging and walking. Soccer, jogging, walking, cricket, and roller skating are the top-five ranked habitual physical activities among Indian boys. The most popular habitual physical activities among European boys are soccer, cricket, bicycling, basketball and walking. African boys play significantly more soccer than Indian boys, but roller skate less than European boys. All other race-specific differences in habitual physical activity are not significant. Indian boys have the highest rates of non-participation in all physical activities (Table 35).

Among Indian boys, 50% or more do not cycle, play catch, baseball, hide and seek, roller skate and play softball. However, while only a small sample (37.4%) of Indian boys roller skate, they skate frequently, making roller skating the fifth highest ranked habitual physical activity of Indian boys. On the other hand, at least one-half of the sample of African boys participate in the eight top ranked sport activities, more than one half of European boys participate in the top-ten ranked habitual physical activities. Indian boys have the lowest rate of participation at high frequencies (6 or more times a week) in cricket, walking, bicycling, catch, basketball, roller-skating and softball.

The top ranked activities among lower SES boys, races combined, are soccer, bicycling, jogging, cricket and walking (Table 36). The top ranked activities among higher SES boys are soccer, bicycling, cricket, walking and jogging. There are no significant SES- or nutritional status-related differences (races combined) in habitual physical activity scores (Tables 36 and 37).

Table 35. Race-specific medians and frequencies of participation in the past 7 days in specific physical activities, and F values.

	African (n=170) Frequency of participation						Indian (n=135) Frequency of participation						European (n=39) Frequency of participation						F
	Md	0	1-2	3-4	5-6	6+	Md	0	1-2	3-4	5-6	6+	Md	0	1-2	3-4	5-6	6+	
Soccer	4	18	21	28	38	74	4	15	20	16	12	60	4	4	5	2	5	15	12.39**
%		10.1	11.7	15.6	21.2	41.3		12.2	16.3	13.0	9.8	48.8		12.9	16.1	6.5	16.1	48.4	
Cricket	3	49	33	23	30	43	2	39	26	20	21	17	3	9	6	2	2	12	2.82
%		27.5	18.5	12.9	16.9	24.2		31.7	21.1	16.3	17.1	13.8		29.0	19.4	6.5	6.5	38.7	
Jogging	3	53	33	39	19	35	3	37	20	25	20	21	3	4	7	10	7	3	0.30
%		29.6	18.4	21.8	10.6	19.6		30.1	16.3	20.3	16.3	17.1		12.9	22.6	32.3	22.6	9.7	
Bicycling	3	59	28	22	22	48	2	62	26	18	6	11	2	10	6	2	3	10	0.44
%		33.0	15.6	12.3	12.3	26.8		50.4	21.1	14.6	4.9	8.9		32.3	19.4	6.5	9.7	32.3	
Walking	2	56	46	28	20	29	2	44	31	16	14	18	3	3	12	5	4	7	0.37
%		31.3	25.7	15.6	11.2	16.2		35.8	25.2	13.0	11.4	14.6		9.7	38.7	16.1	12.9	22.6	
Catch	2	70	47	24	20	18	1	62	26	18	6	11	3	9	6	8	2	6	0.39
%		39.1	26.3	13.4	11.2	10.1		50.4	21.1	14.6	4.9	8.9		29.0	19.4	25.8	6.5	19.4	
Basketball	2	72	42	23	18	24	1	76	17	14	7	9	3	9	4	3	5	9	0.40
%		40.2	23.5	12.8	10.1	13.4		61.8	13.8	11.4	5.7	7.3		30.0	13.3	10.0	16.7	30.0	
Hide And Seek	2	86	34	23	19	16	1	68	24	15	8	8	2	14	4	4	7	2	0.61
%		48.3	19.1	12.9	10.7	9.0		55.3	19.5	12.2	6.5	6.5		45.2	12.9	12.9	22.6	6.5	
Roller-Skating	1	97	29	19	9	25	1	77	20	9	5	12	2	12	8	1	3	7	4.17*
%		54.2	16.2	10.6	5.0	14.0		62.6	16.3	7.3	4.1	9.8		38.7	25.8	3.2	9.7	22.6	
Softball	1	98	39	16	8	18	1	91	16	9	4	3	2	12	4	6	4	5	1.70
%		54.7	21.8	8.9	4.5	10.1		74.0	13.0	7.3	3.3	2.4		38.7	12.9	19.4	12.9	16.1	

* $p<0.05$
** $p<0.01$

Table 36. SES-specific medians and frequencies (races combined) of participation in the past 7 days in specific physical activities, and F values.

	Lower SES (n=118)						Higher SES (n=211)						F
		Frequency of participation						Frequency of participation					
	Md	0	1-2	3-4	5-6	6+	Md	0	1-2	3-4	5-6	6+	
Soccer	3	16	16	19	18	49	4	21	30	27	37	96	1.24
%		13.6	13.6	16.1	15.3	41.5		10.0	14.2	12.8	17.5	45.5	
Cricket	3	33	23	16	24	22	3	63	41	28	29	49	0.21
%		28.0	19.5	13.6	20.3	18.6		30.0	19.5	13.3	13.8	23.3	
Jogging	3	32	24	22	16	24	3	62	36	50	30	33	0.32
%		27.1	20.3	18.6	13.6	20.3		29.4	17.1	23.7	14.2	15.6	
Bicycling	2	41	20	14	16	27	2	76	32	23	30	50	0.01
%		34.7	16.9	11.9	13.6	22.9		36.0	15.2	10.9	14.2	23.7	
Walking	2	39	28	20	15	16	2	64	59	29	22	37	0.19
%		33.1	23.7	16.9	12.7	13.6		30.3	28.0	13.7	10.4	17.5	
Catch	2	50	29	18	12	9	2	88	49	32	16	26	0.29
%		42.4	24.6	15.3	10.2	7.6		41.7	23.2	15.2	7.6	12.3	
Basketball	2	55	23	13	13	14	2	41	39	26	16	27	0.82
%		46.6	19.5	11.0	11.0	11.9		48.6	18.6	12.4	7.6	12.9	
Hide And Seek	2	53	28	16	13	8	1	113	34	24	21	18	0.28
%		44.9	23.7	13.6	11.0	6.8		53.8	16.2	11.4	10.0	8.6	
Roller-Skating	1	70	19	9	5	15	1	114	38	19	12	28	0.40
%		59.3	16.1	7.6	4.2	12.7		54.0	18.0	9.0	5.7	13.3	
Softball	1	68	21	13	7	9	1	131	37	18	9	16	0.92
%		57.6	17.8	11.0	5.9	7.6		62.1	17.5	8.5	4.3	7.6	

The % of participation per group is given below the participation rates (numbers) for each category.
*$p<0.05$
**$p<0.01$

Table 37. Nutritional status-specific medians and frequencies (races combined) of participation in the past 7 days in specific physical activities.

	Undernourished (n=86) Frequency of participation						Nutritionally normal (n=184) Frequency of participation						Overweight (n=44) Frequency of participation						F
	Md	0	1-2	3-4	5-6	6+	Md	0	1-2	3-4	5-6	6+	Md	0	1-2	3-4	5-6	6+	
Soccer	4	13.0	13.0	11.0	13.0	36.0	4	14	27	23	36	84	4	7	3	11	5	18	1.69
%		15.1	15.1	12.8	15.1	41.9		7.6	14.7	12.5	19.6	45.7		15.9	6.8	25.0	11.4	40.9	
Cricket	2	24.0	21.0	12.0	15.0	14.0	3	52	33	22	30	47	2	16	8	5	7	8	1.45
%		27.9	24.4	14.0	17.4	16.3		28.3	17.9	12.0	16.3	25.5		36.4	18.2	11.4	15.9	18.2	
Jogging	3	24	17.0	22.0	10.0	13.0	3	49	36	38	27	34	3	17	4	7	8	8	0.22
%		27.9	19.8	25.6	11.6	15.1		26.6	19.6	20.7	14.7	18.5		38.6	9.1	15.9	18.2	18.2	
Bicycling	2	29	20	9	15	13	2	64	30	21	17	52	3	19	1	4	10	10	0.61
%		33.7	23.3	10.5	17.4	15.1		34.8	16.3	11.4	9.2	28.3		43.2	2.3	9.1	22.7	22.7	
Walking	2	29.0	24.0	11.0	13.0	9.0	2	51	50	29	20	34	2	17	8	7	3	9	0.76
%		33.7	27.9	12.8	15.1	10.5		27.7	27.2	15.8	10.9	18.5		38.6	18.2	15.9	6.8	20.5	
Catch	2	36	21	16	6	7	2	76	42	26	18	22	2	19	14	3	4	4	0.35
%		41.9	24.4	18.6	7.0	8.1		41.3	22.8	14.1	9.8	12.0		43.2	31.8	6.8	9.1	9.1	
Basketball	2	40	17	10	5	14	2	83	37	22	20	21	1	25	7	4	3	5	0.62
%		46.5	19.8	11.6	5.8	16.3		45.4	20.2	12.0	10.9	11.5		56.8	15.9	9.1	6.8	11.4	
Hide And Seek	2	42	18	11	10	5	2	85	36	22	22	19	1	29	5	6	2	1	0.20
%		48.8	20.9	12.8	11.6	5.8		46.2	19.6	12.0	12.0	10.3		67.4	11.6	14.0	4.7	2.3	
Roller-Skating	1	51	16	8	2	9	1	100	31	17	12	24	1	24	8	1	3	8	0.84
%		59.3	18.6	9.3	2.3	10.5		54.3	16.8	9.2	6.5	13.0		54.5	18.2	2.3	6.8	18.2	
Softball	1	53	14	12	4	3	1	104	38	13	10	19	1	30	6	5	1	2	1.59
%		61.6	16.3	14.0	4.7	3.5		56.5	20.7	7.1	5.4	10.3		68.2	13.6	11.4	2.3	4.5	

The % of participation per group is given below the participation rates (numbers) for each category.
*$p<0.05$
**$p<0.01$

Research Question One

To answer the question: "Are there significant SES, race and nutritional status differences in the growth status of 10 year old South African boys?", MANOVA and MANCOVA were performed. Race, SES and nutritional status were entered as the independent variables and growth (stature and mass), proportions (sitting height/stature and bicristal/biacromial ratio), and body composition (Σ 5 skinfolds; trunk/extremity skinfold ratio; estimated arm musculature) as the dependent variables. The effects of SES, race and nutritional status were explored independently, while the effects of the other two variables (SES and nutritional status) were controlled statistically. SES and race were entered as dummy variables (0-1, and 0-1-2 respectively), and nutritional status was entered as a categorical variable (1-2-3). Interactions of SES, race and nutritional status were also examined. Specific between group differences for all significant MANOVAs were tested using the pairwise comparisons of estimated marginal means when SES, race and/or nutritional status were used as covariates. Marginal means are defined as the unconditional distribution of a single variable or a combination of variables in a multivariate distribution without regard to the values of the independent variables (Marriott, 1990; Kotz and Johnson, 1985).

Regression analyses of SES, race and nutritional status on growth status variables were conducted to determine how much of the variation in growth status could be attributed to SES, race or nutritional status (Table 38). Some of the variation in growth (stature and mass) is explained by SES and nutritional status differences. Race, however, does not contribute significantly to the variation in stature or mass. SES accounts for a small proportion (4%) of the variation in stature, and nutritional status differences account for an additional 3% of the variation in stature. Nutritional status, on the other hand, accounts for a large proportion (58%) of the variation in mass, with SES accounting for an additional 2% of the variation. However, only a small proportion (3%) of the difference in the sitting height/stature ratio is accounted for by nutritional status, while race explains another 2% of the variation. Approximately 4% of the variation in the bicristal/biacromial ratio is due to race, and SES differences account for an additional 1% of the variation. Nutritional status differences account for 49% of the variation in total fatness (sum of 5 skinfolds), 15% of the variation in the TER, and 5% of the variation in estimated AMA. Race accounts for an additional 2% of the variation in total fatness, and 1% of the difference in estimated AMA.

MANCOVA analyses were used to explore the effects of SES, race and nutritional status independently on growth (Table 39). Race differences in growth (stature and mass) are not significant when the effects of nutritional status and SES are controlled statistically. When the effects of nutritional status and race are controlled statistically, higher SES boys are taller and heavier than lower SES boys (Table 40). Overweight boys are heavier than undernourished and nutritionally normal boys, and nutritionally normal boys are heavier than undernourished boys, when SES and race are used as covariates. There are no significant SES, race, and/or nutritional status interactions.

There are significant race differences in proportions. European boys have proportionally shorter legs relative to stature than African or Indian boys when SES and

Table 38. Regression analysis of selected growth status variables by SES, race and nutritional status for total sample (n=380).

Dependent Variable	Independent Variable	R^2	B-value[a]	β[b]	F
Growth					
Stature (cm)	SES	0.04	2.6	0.19	14.04**
	SES +	0.07	2.36	0.17	13.06**
	Nutritional status		1.85	0.17	
Mass (kg)	Nutritional status	0.58	8.25	7.63	527.60**
	Nutritional status +	0.60	8.12	7.51	280.70**
	SES		1.73	0.13	
Proportions					
Sitting height/stature ratio, %	Nutritional status	0.03	0.58	0.18	13.16**
	Nutritional status +	0.05	0.62	0.19	9.84**
	Race		0.36	0.13	
Bicristal/biacromial ratio, %	Race	0.04	1.50	0.20	15.10**
	Race +	0.05	1.83	0.24	10.76**
	SES		-1.13	-0.13	
Body Composition					
Σ of 5 SF (mm)	Nutritional status	0.49	31.27	0.70	360.85
	Nutritional status +	0.51	31.75	0.71	193.89**
	Race		5.52	0.14	
TER (mm/mm)	Nutritional status	0.15	0.16	0.39	68.47
AMA (cm)	Nutritional status	0.05	2.90	0.22	18.34**
	Nutritional status +	0.06	3.02	0.22	12.17**
	Race		1.50	0.12	

[a]regression coefficient　　[b] standardized regression coefficient

* p<0.05　　** p<0.01

Table 39. Summary table of MANOVA and MANCOVA F-values for SES, race and nutritional status effects on growth status.

				Covariate						
				SES NS	Race NS	Race SES				
Independent Variable	Race	SES	NS	Race	SES	NS	SES * Race	SES * NS	Race * NS	SES * Race * NS
Growth										
Stature (cm)	1.79	4.69*	2.86	0.98	8.75**	7.61	1.22	1.21	2.08	0.05
Mass (kg)	0.36	8.55**	180.87**	1.09	10.03**	352.63**	0.61	0.29	1.49	0.03
Proportions										
SH/ST, %	5.33**	1.67	5.47**	10.18**	3.14	9.42**	0.26	0.05	0.39	0.31
BBR, %	9.35**	6.61**	0.81	11.90**	7.21**	1.98	1.04	0.39	1.14	0.61
Body Composition										
Σ of 6 SF (mm)	7.92**	2.22	204.99**	17.65**	2.64	372.57**	0.04	0.06	1.14	0.53
TER (mm/mm)	7.94**	1.99	22..14**	14.75**	0.02	52.72**	0.01	2.36	0.97	0.16
AMA (cm)	1.60	1.57	9.65**	2.90	2.12	12.59**	2.84	1.78	2.09	4.75**

* p<0.05　　** p<0.01

Table 40. Pairwise comparisons of estimated marginal means for selected growth status variables with significant F ratios of nutritional status, race and SES groups with nutritional status, race and SES as covariates.

	NS	Mean[a]	NS	Mean[a]	MD[b]
Mass, kg	UN	29.1	NN	32.2	-5.19**
	UN	29.1	OW	44.6	-17.58**
	NN	32.2	OW	44.6	-12.39**
Sitting height/stature ratio, %	UN	49.7	NN	50.6	-0.92**
	UN	49.7	OW	50.9	-1.19**
	NN	50.6	OW	50.9	-0.28
Σ of 5 Skinfolds, mm	UN	30.9	NN	43.0	-12.03**
	UN	30.9	OW	101.7	-70.79**
	NN	43.0	OW	101.7	-58.77**
Trunk/Extremity Ratio, %	UN	0.97	NN	1.03	-0.05**
	UN	0.97	OW	1.40	-0.38**
	NN	1.03	OW	1.40	-0.33**
AMA, cm	UN	28.8	NN	29.9	-1.05
	UN	28.8	OW	35.4	-6.55**
	NN	29.9	OW	35.4	-5.50**

	SES	Mean[a]	SES	Mean[a]	MD[b]
Stature, cm	Lower	137.1	Higher	139.2	-2.11**
Mass, kg	Lower	31.7	Higher	33.2	-1.53**
Bicristal/biacromial ratio, %	Lower	70.1	Higher	68.6	1.53**

	Race	Mean[a]	Race	Mean[a]	MD[b]
Sitting height/stature ratio, %	African	50.3	Indian	50.2	0.04
	African	50.3	European	51.7	-1.41**
	Indian	50.2	European	51.7	-1.45**
Bicristal/biacromial ratio, %	African	68.2	Indian	69.5	-1.37*
	African	68.2	European	72.5	-4.34**
	Indian	69.5	European	72.5	-2.98**
Σ of 5 skinfolds, mm	African	43.7	Indian	56.0	-12.26**
	African	43.7	European	45.4	-1.89
	Indian	56.0	European	45.4	10.36**
Trunk/extremity ratio, %	African	1.03	Indian	1.15	-0.12**
	African	1.03	European	0.98	0.05
	Indian	1.15	European	0.98	0.17**
AMA, cm	African	29.5	Indian	31.7	-2.19*
	African	29.5	European	30.7	-1.25
	Indian	31.7	European	30.7	0.94

[a] Adjusted means
[b] MD = mean difference
* p<0.05
** p<0.01

nutritional status are used as covariates. European boys have proportionally broader hips relative to the shoulders than African and Indian boys when the effects of nutritional status and SES are removed statistically. Further, Indian boys have proportionally broader hips relative to the shoulders compared to African boys.

Nutritional status-related differences in the sitting height/stature ratio are significant when SES and race are used as covariates. Undernourished boys have proportionally longer legs relative to their stature than nutritionally normal or overweight boys, when the effects of SES and race are controlled.

SES differences in bicristal/biacromial ratio indicate that higher SES boys have proportionally broader hips relative to their shoulders compared to lower SES boys when the effects of race and nutritional status are controlled. There are no significant interaction effects of SES, race and/or nutritional status on the sitting height/stature and bicristal/biacromial ratios, and there are no significant SES, race and/or nutritional status interactions for proportions.

There are significant race differences in total skinfolds and TER when SES and nutritional status are used as covariates. Indian boys are fatter and have proportionally more fat on the trunk compared to the extremities than African and European boys when SES and nutritional status are entered as covariates. Additionally, Indian boys have larger estimated arm muscle areas compared to African boys, which are related to the larger accumulation of subcutaneous adipose tissue. When the effects of SES and race are controlled statistically, nutritional status differences in total fatness, TER and estimated AMA are significant.

Overweight boys have larger accumulations of estimated SAT on the trunk relative to the extremities than undernourished and nutritionally normal boys, and nutritionally normal boys more than undernourished boys, when the effects of SES and race are removed statistically. Overweight boys have larger estimated arm muscle areas than undernourished and nutritionally normal boys when race and SES are used as covariates. Nutritionally normal and overweight boys do not differ significantly.

There is a significant SES, race and nutritional status interaction for estimated arm muscle area (Figure 2). Nutritionally normal Indian boys from lower SES families have smaller estimated arm muscle areas compared to both undernourished and overweight lower SES Indian boys. On the other hand, both higher and lower SES African boys and higher SES Indian boys demonstrate a linear increase in estimated AMA with improved nutritional status. Additionally, overweight African boys from higher SES families have a markedly higher estimated AMA compared to nutritionally normal African boys from higher SES families.

Research Question Two

To answer the question: "Are there significant race, SES and nutritional status differences in the health- and performance-related fitness of 10 year old South African boys?", MANCOVAs were conducted, and specific between group differences for all significant MANCOVAs were tested using pairwise comparisons of estimated marginal means. The estimated marginal means procedure uses the predicted means without correcting for covariates, thus allowing for pairwise comparisons between groups.

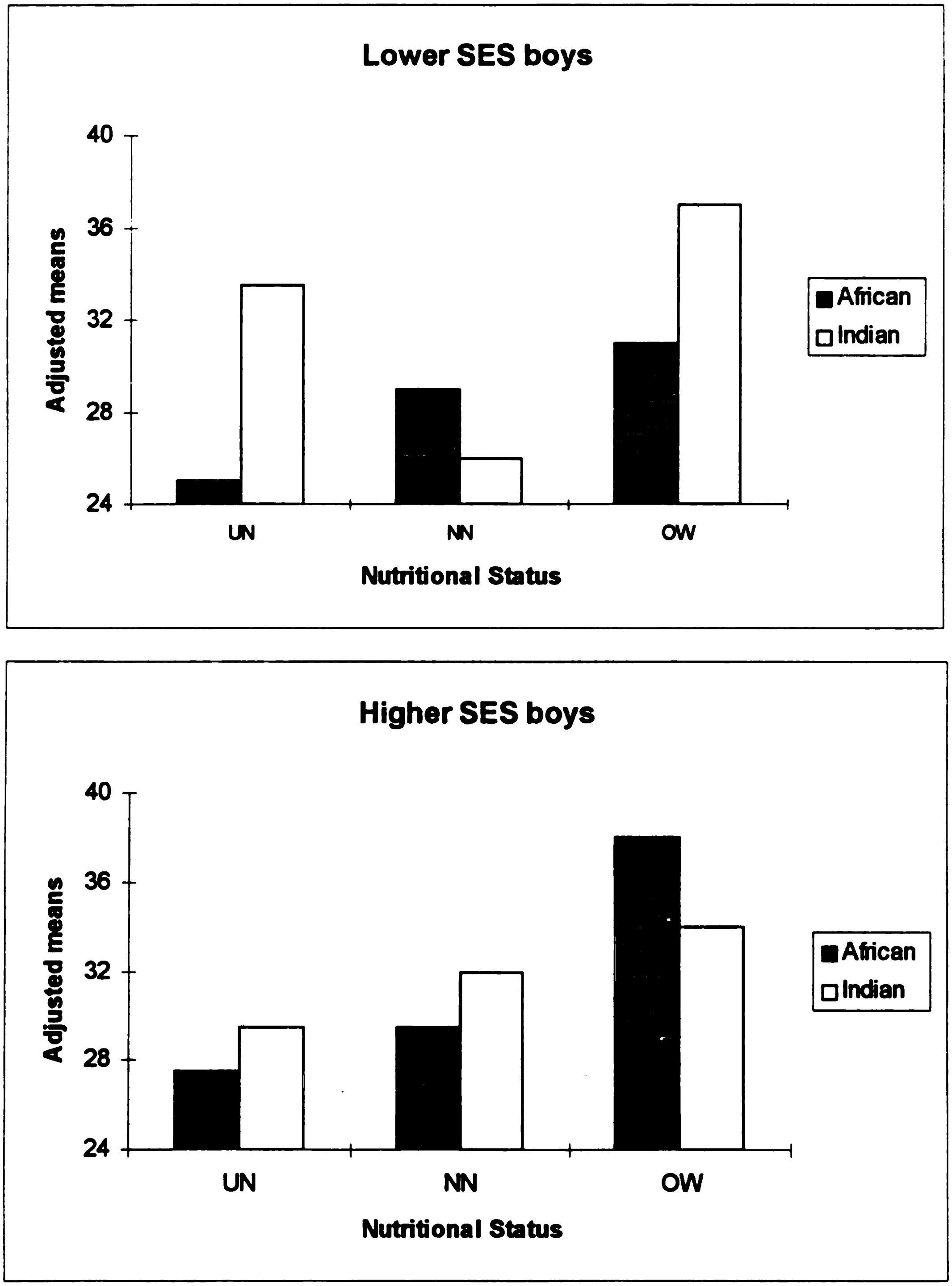

Figure 2. SES adjusted means for nutritional status - race interactions by SES for estimated arm muscle area.

Regression analyses of race, SES and nutritional status on the components of health-related and performance-related fitness were also conducted. Components of health-related fitness include sit-ups, push-ups, 9 minute run, sit and reach, and the sum of 5 skinfolds, while components of performance-related fitness include the dash, shuttle run, grip strength, and standing long jump. The effects of race, SES and nutritional status were considered individually, after the effects of the other two independent variables were removed statistically.

Health-related fitness

SES and race do not contribute significantly to differences in sit-ups, and nutritional status and SES do not contribute significantly to variation in the push-ups, distance run and sit and reach (Table 41). Nutritional status accounts for only 1% of the variation in sit-ups, while race accounts for 3%, 2% and 5% of the variation in push-ups, distance run, and sit and reach, respectively. Nutritional status accounts for 49% of the variation in the sum of skinfolds, and race accounts for an additional 2% of the variation in skinfold thicknesses.

The effects of race on health-related fitness were explored independently with SES and nutritional status used as covariates (Tables 42 and 43). There are significant race differences in push-ups, the distance run, sit and reach, and the sum of skinfolds when the effects of SES and nutritional status are controlled statistically. European boys complete more push-ups in 30 seconds and have greater endurance on the 9 minute run compared to African and Indian boys, who do not differ. However, African boys have

Table 41. Regression analysis of selected physical fitness variables by SES, race and nutritional status for total sample (n=380).

Dependent Variable	Independent variable	R^2	B-value[a]	β[b]	F
Health-related fitness					
Sit-ups, #/30 sec	Nutritional status	0.01	-0.97	-0.10	4.15*
Push-ups, #/30 sec	Race	0.03	2.09	0.17	10.99**
9 minute run, m	Race	0.02	76.36	0.14	7.16**
Sit and reach, cm	Race	0.05	-2.00	-0.23	19.77**
Σ of 5 SF (mm)	Nutritional status	0.49	31.27	0.70	360.85
	Nutritional status +	0.51	31.75	0.71	193.89**
	Race		5.52	0.14	
Performance-related fitness					
Dash, sec	Nutritional status	0.01	0.21	0.10	3.95*
Grip, kg	Nutritional status	0.11	1.88	0.33	45.14**
	Nutritional status +	0.13	1.81	0.32	25.99**
	SES		0.88	0.12	
Grip, kg/kg	Nutritional status	0.22	-0.08	-0.47	100.12
	Nutritional status +	0.23	-0.08	-0.48	52.65
	Race		-0.02	-0.10	

[a]regression coefficient
[b] standardized regression coefficient
* p<0.05
** p<0.01

Table 42. Summary table of MANOVA and MANCOVA F-values for SES, race and nutritional status effects on physical fitness.

				Covariate						
				SES NS	Race NS	Race SES				
Independent variable	Race	SES	NS	Race	SES	NS	Race * SES	Race * NS	SES * NS	Race * SES * NS
Health-related fitness										
Sit-ups (#)	1.80	1.75	3.85*	1.09	1.19	12.02**	3.39	1.81	0.20	1.34
Push-ups (#)	2.71	0.00	2.64	5.23**	0.09	5.68**	2.28	0.15	0.00	0.08
9 minute run (m)	0.11	1.46	11.65**	12.44**	0.39	9.17**	1.67	4.40**	0.50	0.12
Sit and reach (cm)	11.56**	1.02	1.66	14.51**	0.92	4.49**	0.82	0.31	0.99	1.94
Σ of 5 skinfolds (mm)	7.34**	1.98	197.84**	15.26**	1.54	344.60**	0.02	0.87	0.02	0.48
Performance-related fitness										
Dash (sec)	3.99*	0.15	5.13**	4.74**	0.05	6.53**	1.59	1.09	0.08	1.72
Grip (kg)	0.90	7.05**	8.00**	2.34	7.77**	19.42**	0.63	0.88	0.56	0.49
Grip (kg/kg)	1.09	0.45	36.96**	3.77*	0.13	60.11**	0.07	0.53	0.25	0.46
Shuttle run (sec)	0.07	0.82	0.69	1.08	0.80	1.15	4.66*	1.02	0.05	0.73
Long jump (cm)	1.55	0.01	3.70*	2.00	0.81	2.28	0.47	3.29**	0.62	0.98

* p<0.05
** p<0.01

Table 43. Pairwise comparisons of estimated marginal means for selected health-related fitness variables with significant F ratios of nutritional status, race and SES groups with nutritional status, race and SES as covariates.

	Race	Mean[a]	Race	Mean[a]	MD[b]
<u>Health-related fitness</u>					
Push-ups, #/30 sec	African	23.6	Indian	25.2	-1.54
	African	23.6	European	28.4	-4.75**
	Indian	25.2	European	28.4	-3.21*
9 minute run, m	African	1610	Indian	1560	50.75
	African	1610	European	1887	-276.87**
	Indian	1560	European	1887	-327.62**
Sit and reach, cm	African	27.8	Indian	24.2	3.63**
	African	27.8	European	25.9	1.91
	Indian	24.2	European	25.9	-1.72
Σ of 5 skinfolds, mm	African	43.8	Indian	55.7	-11.91**
	African	43.8	European	45.8	-2.04
	Indian	55.7	European	45.8	9.87**
<u>Performance-related fitness</u>					
Dash, sec	African	9.4	Indian	9.8	-0.39**
	African	9.4	European	9.3	0.06
	Indian	9.8	European	9.3	0.45*
Grip, kg/kg	African	0.61	Indian	0.58	0.03**
	African	0.61	European	0.59	0.02
	Indian	0.58	European	0.59	-0.01

	SES	Mean[a]	SES	Mean[a]	MD[b]
<u>Performance-related fitness</u>					
Grip, kg	Lower	18.4	Higher	19.5	-1.05**

[a] Adjusted means
[b] MD = mean difference
* $p<0.05$
** $p<0.01$

Table 43. (continued)

	NS[a]	Mean[b]	NS	Mean[c]	MD[b]
<u>Health-related fitness</u>					
Sit-ups, #/30 sec	UN	16	NN	17.4	-1.40*
	UN	16	OW	13.4	2.63**
	NN	17.4	OW	13.4	4.03**
Push-ups, #/30 sec	UN	23.9	NN	25.8	-1.88
	UN	23.9	OW	21.8	2.11
	NN	25.8	OW	21.8	4.00**
9 minute run, m	UN	1595	NN	1676	-80.90
	UN	1595	OW	1439	156.30*
	NN	1676	OW	1439	237.21**
Sit and reach, cm	UN	24.9	NN	27.0	-2.03**
	UN	24.9	OW	26.4	-0.43
	NN	27.0	OW	26.4	1.60
Σ of 5 skinfolds, mm	UN	30.9	NN	43.0	-12.05**
	UN	30.9	OW	101.2	-70.53**
	NN	43.0	OW	101.5	-58.48**
<u>Performance-related fitness</u>					
Dash, sec	UN	9.5	NN	9.4	0.11
	UN	9.5	OW	10.1	-0.55**
	NN	9.4	OW	10.1	-0.66**
Grip, kg	UN	17.5	NN	19.25	-1.73**
	UN	17.5	OW	21.0	-3.52**
	NN	19.3	OW	21.0	-1.80**
Grip, kg/kg	UN	0.65	NN	0.60	0.05**
	UN	0.65	OW	0.47	0.18**
	NN	0.60	OW	0.47	0.13**
Standing long jump, cm	UN	149.0	NN	153.5	-4.58**
	UN	149.0	OW	147.9	1.08
	NN	153.5	OW	147.9	5.66

[a] UN: undernourished, NN: nutritionally normal, and OW: overweight.
[b] Adjusted means
[c] MD = mean difference
* $p<0.05$
** $p<0.01$

greater flexibility of the lower back on the sit and reach compared to Indian boys. There are no significant SES differences in health-related fitness.

Race and SES were used as covariates to explore the independent effects on nutritional status on health-related fitness. There are significant nutritional status differences in the sit-ups, push-ups, distance run, sit and reach, and total fatness when SES and race are entered as covariates. Undernourished and nutritionally normal boys complete more sit-ups in 30 seconds and run farther in nine minutes compared to overweight boys. Nutritionally normal boys have better performances on the sit-ups and sit and reach compared to undernourished boys. Additionally, nutritionally normal boys have greater endurance of the arms and shoulder girdle on the push-ups compared to overweight boys.

There is a significant race by nutritional status interaction for the 9 minute run (Figure 3). Nutritionally normal Indian boys run a shorter distance in nine minutes compared to undernourished Indian boys, whereas undernourished African and European boys have poorer endurance on the distance run compared to nutritionally normal African and European boys. All other SES, race and nutritional status interactions on health-related fitness are not significant.

Performance-related fitness

SES, race and nutritional status do not contribute significantly to the variation in the shuttle run and standing long jump (Table 41). SES and race also do not contribute significantly to the variation in the dash, while nutritional status accounts for only 1% of the variation. Nutritional status accounts for 11% of the variation in absolute grip

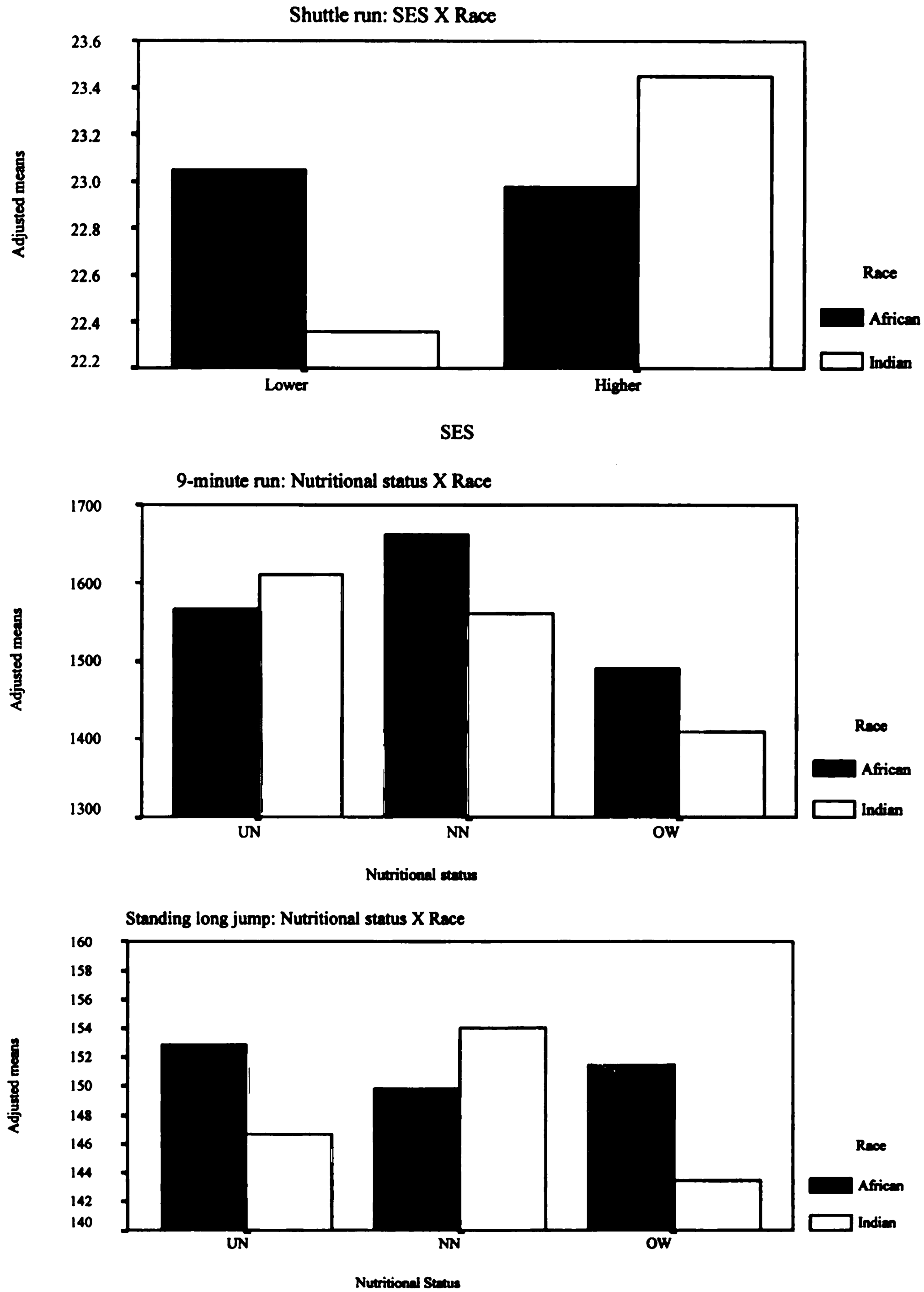

Figure 3. Adjusted means and interaction effects for the shuttle run (Race X SES), 9 minute run (Nutritional status X Race), and standing long jump (Nutritional status X Race).

strength (kg), and 22% of the variation in grip strength relative to body mass (kg/kg). SES accounts for an additional 2% of the variation in absolute grip strength (kg), while race accounts for an additional 1% of the variation in relative grip strength (kg/kg).

The effects of SES, race and nutritional status on performance-related fitness were explored independently using MANCOVA (Tables 42 and 43). When the effects of SES and nutritional status are controlled statistically, race-specific differences in the dash and grip (kg/kg) are significant. African and European boys have greater speed in the dash compared to Indian boys. Further, African boys have greater grip strength per kilogram body weight compared to Indian boys when the effects of SES and nutritional status are statistically removed.

There is a significant SES difference in absolute grip strength when race and nutritional status are used as covariates. Higher SES boys have greater absolute grip strength compared to lower SES boys. This, however, is an artifact of the larger body size of higher SES boys, since differences in grip strength relative to kilogram body mass are not significant.

When the effects of SES and race are statistically removed, overweight boys have poorer performances on the 50 meter dash compared to undernourished and nutritionally normal boys. Overweight boys have greater absolute grip strength compared to undernourished and nutritionally normal boys, and nutritionally normal boys have better absolute grip strength compared to undernourished boys, when race and SES are controlled statistically. However, undernourished boys have greater grip strength per kilogram body mass compared to nutritionally normal and overweight boys, and nutritionally normal boys have greater grip strength per kilogram mass compared to overweight boys.

There are significant race by nutritional status interactions for the standing long jump and SES by race interactions for the shuttle run (Figure 3). Lower SES Indian boys have better performances on the shuttle run compared to higher SES Indian boys. On the other hand, lower SES African boys have poorer performances on the shuttle run compared to higher SES African boys. Nutritionally normal African boys have poorer performances on the standing long jump compared to undernourished and overweight African boys. Both nutritionally normal Indian and European boys have better explosive strength on the standing long jump compared to undernourished and overweight Indian and European boys respectively. All other interaction effects for performance-related fitness are not significant.

Research Question Three

To answer the question: "Are there SES, race and nutritional status differences in the habitual physical activity of 10 year old South African boys?" MANOVA was performed. Habitual physical activity was assessed as the time spent on light activity (3 to 5 METS) and MVPA (6 to 9 METS), and mean estimated total daily energy expenditure. Stepwise regression analyses were conducted to determine which sociodemographic factor (SES, race and nutritional status) was the most powerful predictor of sedentary, light and moderate to vigorous physical activity (Table 44).

Nutritional status accounts for 46% and 41% of the variation in absolute (kcal/day) and relative (kcal/kg/day) estimated energy expenditure in sedentary activity, respectively. SES accounts for an additional 2% of the variation in sedentary activity. Nutritional status accounts for approximately 16% of the variation in estimated energy expenditure (kcal/day) in light activity, but does not account for any of the variance in estimated energy expenditure in light activity per kilogram body mass. Nutritional status explains 2% of variation in estimated energy expenditure in MVPA (kcal/day), and race contributes another 1%. On the other hand, race accounts for 2% of the variation in MVPA (kcal/kg/day).

Table 44. Regression analysis of components of the energy expenditure by SES, race and nutritional status for total sample (n=228).

Dependent variable	Independent Variable	R^2	Beta-value[a]	β^b	F
Estimated energy expenditure (kcal/day)					
Sedentary	Nutritional status	0.46	183.50	0.68	277.07**
	Nutritional status	0.48	178.82	0.66	148.73**
	SES		46.66	0.14	148.73**
Light	Nutritional status	0.16	81.68	0.40	60.95**
MVPA	Nutritional status	0.02	39.46	0.14	6.17*
	Nutritional status	0.03	35.54	0.12	5.25**
	Race		-30.73	-0.11	
Total	Nutritional status	0.41	304.64	0.64	221.42**
Estimated energy expenditure (kcal/kg/day)					
Sedentary	Race	0.04	-1.65	-0.19	11.76**
MVPA	Race	0.02	-1.07	-0.13	5.49*

[a]regression coefficient
[b] standardized regression coefficient
* $p<0.05$
** $p<0.01$

Variation in estimated energy expenditure (kcal/day) in sedentary and light activity among racial groups is confounded by SES and nutritional status. When the effects of SES and nutritional status are controlled statistically, racial variation in sedentary and light estimated energy expenditure (kcal/day) is not significant (Table 45). There are, however, differences in MVPA and mean daily total estimated energy expenditure (kcal/day) when SES and nutritional status are used as covariates. African and European boys are more active at higher intensities of estimated energy expenditure compared to Indian boys (Table 46). The differences remain significant when MVPA is expressed per kilogram body mass. African boys have a higher daily total estimated energy expenditure (kcal/day) compared to Indian boys, but expressed relative to body mass, both African and European boys are more active than Indian boys.

Table 45. MANOVA of estimated energy expenditure variables by SES, race and nutritional status for total sample (n=228).

				Covariates						
				NS and SES	NS and Race	Race and SES				
	RACE	SES	NS	Race	SES	NS	RACE * SES	RACE * NS	SES * NS	RACE * SES * NS
Estimated energy expenditure (kcal/day)										
Sedentary	4.12*	7.49**	40.51**	2.34	9.80**	159.21**	0.26	0.10	0.75	0.37
Light	4.88**	0.84	17.99**	2.68	0.07	31.13**	0.60	0.21	0.76	0.19
MVPA	6.00**	0.60	2.06	8.52**	0.20	2.78	0.05	0.60	0.45	0.28
Total	4.92**	0.11	41.97**	5.45**	1.40	111.13**	0.24	0.87	0.64	0.08
Estimated energy expenditure (kcal/kg/day)										
Sedentary	3.96*	0.66	1.60	3.81*	2.29	0.39	0.01	0.64	1.65	0.11
Light	5.80**	2.38	3.77*	4.18*	1.52	1.47	0.20	0.11	1.20	0.24
MVPA	6.92**	1.20	0.09	10.01**	1.11	2.37	0.34	0.40	0.63	0.31
Total	9.73**	2.85	0.31	14.27**	1.40	1.83	0.06	0.53	3.36*	0.62

* $p<0.05$ ** $p<0.01$

SES variation in absolute estimated energy expenditure in sedentary (kcal/day) activity is significant when the effects of race and nutritional status are controlled. Higher SES boys are more sedentary (kcal/day) than lower SES boys. This is an artifact of body size, since SES differences in estimated energy expenditure in sedentary (kcal/kg/day) activity are not significant when expressed in terms of body mass.

Table 46. Pairwise comparisons of estimated marginal means for selected physical activity variables with significant F ratios of nutritional status, race and SES groups with nutritional status, race and SES as covariates.

	Race	Mean[a]	Race	Mean[a]	MD[b]
Estimated energy expenditure (kcal/day)					
MVPA	African	302.2	Indian	222.4	79.88**
	African	302.2	European	314.5	-12.31
	Indian	222.4	European	314.5	-92.19**
Total	African	1285	Indian	1198.6	86.12**
	African	1285	European	1281.3	3.42
	Indian	1199	European	1281.3	-82.70
Estimated energy expenditure (kcal/kg/day)					
Sedentary	African	22.0	Indian	22.3	-0.25
	African	22.0	European	21.1	0.92*
	Indian	22.3	European	21.1	1.17**
Light	African	8.3	Indian	7.2	1.05**
	African	8.3	European	8.6	-0.33
	Indian	7.2	European	8.6	-1.38*
MVPA	African	9.5	Indian	6.8	2.68**
	African	9.5	European	9.8	-0.26
	Indian	6.8	European	9.8	-2.94**
Total	African	39.9	Indian	36.4	3.48**
	African	39.9	European	39.5	0.33
	Indian	36.4	European	39.5	-3.15**
	SES	Mean[a]	SES	Mean[a]	MD[b]
Estimated energy expenditure (kcal/day)					
Sedentary	Lower	690.6	Higher	736.2	-45.69**
	NS	Mean[a]	NS	Mean[a]	MD[b]
Estimated energy expenditure (kcal/day)					
Sedentary	UN	594.7	NN	710.3	-115.67**
	UN	594.7	OW	978.2	-383.55**
	NN	710.3	OW	978.2	-267.88**
Light	UN	200.2	NN	257.0	-56.78**
	UN	200.2	OW	371.4	-171.21**
	NN	257.0	OW	371.4	-114.43**
Total	UN	1030	NN	1250	-219.93**
	UN	1030	OW	1654	-624.12**
	NN	1250	OW	1654	-404.19**

[a] Adjusted means
[b] MD = mean difference
* $p<0.05$ ** $p<0.01$

Variation in sedentary, light and total estimated energy expenditure (kcal/day) by nutritional status are significant when the effects of SES and race are removed statistically. Nutritional status variation is related to body size as differences are not significant when expressed per unit mass.

The interactions of SES and nutritional status in daily total estimated energy expenditure (kcal/kg/day) are significant (Figure 4). Mean daily total estimated energy expenditure per unit mass (kcal/kg/day) of undernourished lower SES boys is higher than that of nutritionally normal and overweight lower SES boys. Nutritionally normal lower SES boys have a higher mean daily total estimated energy expenditure per unit mass compared to overweight lower SES boys. The mean daily total estimated energy expenditure per unit mass (kcal/kg/day) of nutritionally normal higher SES boys is higher than that of undernourished and overweight higher SES boys. Undernourished higher SES boys have lower mean daily total estimated energy expenditure per unit mass than overweight higher SES boys. All other SES, race and/or nutritional status interactions are not significant.

Research Question Four

To answer the question: "Are there nutritional status differences in habitual physical activity of 10 year old South African boys grouped by race?" MANOVA was performed. The effects of SES were controlled statistically. Estimated energy expenditure was sorted into sedentary (1 - 2 METS), light (3 to 5 METS), MVPA (6 - 9 METS) and total daily energy expenditure. Stepwise regression analyses were conducted

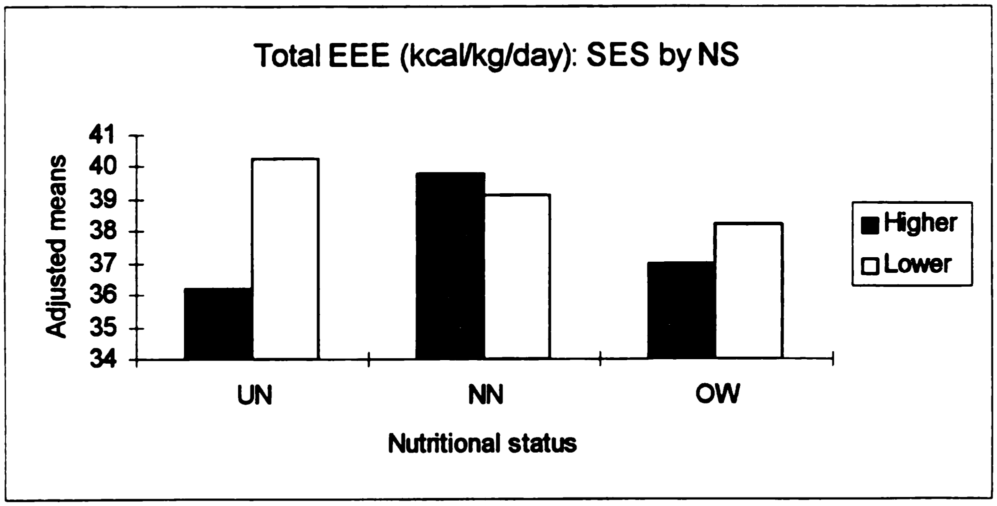

Figure 4. Adjusted means for the interaction of SES and nutritional status on daily total estimated energy expenditure (kcal/kg/day).

to determine if nutritional status was a significant predictor of sedentary, light and moderate to vigorous physical activity.

There is significant nutritional status variation in estimated energy expenditure in sedentary, light and total activity of African boys (Tables 47-49). This, however, is a factor of body size since there are no differences in estimated energy expenditure relative to body mass of African boys. In contrast, nutritional status variations in all categories of absolute estimated energy expenditure (sedentary, light, MVPA and total) is significant for Indian boys, and the differences for MVPA and total estimated energy expenditure of Indian boys remain significant when expressed per unit mass. Undernourished Indian boys engage in less MVPA (kcal/kg/day) compared to nutritionally normal and overweight Indian boys. Additionally, overweight Indian boys have higher mean daily total estimated energy expenditure relative to body mass compared to nutritionally normal boys. Differences in MVPA and mean daily total estimated energy expenditure between undernourished and nutritionally normal Indian boys are not significant. There are nutritional status differences in absolute estimated energy expenditure in light, total and habitual physical activity (PAQ-C Score) of the small sample of European boys. When estimated energy expenditure is expressed relative to body mass, overweight European boys engage in more light activity and have a higher PAQ-C Score compared to undernourished and nutritionally normal European boys.

Stepwise regression analyses were conducted to determine how much of the variation in estimated energy expenditure of the total sample was explained by nutritional status (Table 50). Nutritional status explains 2% to 44% of the variation in estimated energy expenditure in the total sample. When estimated energy expenditure is expressed per unit mass, a smaller proportion of the variation (4% versus 39%) in mean daily total estimated energy expenditure is explained by nutritional status. On the other hand, nutritional status explains only 2% of the variation in both absolute and relative estimated energy expenditure in MVPA.

Table 47. Summary table of race specific ANCOVA F values, controlling for SES, of nutritional status differences in estimated energy expenditure (kcal/day and kcal/kg/day).

	African	Indian	European
Estimated energy expenditure (kcal/day)			
Sedentary	48.55**	56.78**	1.53
Light	5.96**	5.77**	6.99**
MVPA	0.50	5.04**	0.87
Total	35.05**	33.93**	4.12*
Estimated energy expenditure (kg/day)			
Sedentary	0.21	0.58	0.99
Light	0.74	1.55	3.54*
MVPA	0.18	3.72*	0.60
Total	0.16	5.51**	0.97
PAQ-C Score	0.29	0.29	6.08**

Table 48. Pairwise comparisons of estimated marginal means for selected estimated energy expenditure (kcal/day) and physical activity variables with significant F ratios of nutritional status for African, Indian and European boys.

	NS	Mean[a]	NS	Mean[a]	MD[b]
		African			
Sedentary	UN	590.7	NN	704.0	-121.47**
	UN	590.7	OW	968.1	-401.84**
	NN	704.0	OW	968.1	-280.37**
Light	UN	207.8	NN	269.7	-23.26
	UN	207.8	OW	388.0	-124.14**
	NN	269.7	OW	388.0	-100.88**
Total	UN	113	NN	1271	-138.85**
	UN	113	OW	1699	-571.61**
	NN	1271	OW	1699	-432.76**
		Indian			
Sedentary	UN	592.7	NN	719.	-129.38**
	UN	592.7	OW	101.9	-440.67**
	NN	719.0	OW	101.9	-311.29**
Light	UN	185.2	NN	230.1	-64.63*
	UN	185.2	OW	339.2	-104.20**
	NN	230.1	OW	339.2	-39.57
MVPA	UN	178.2	NN	236.6	-104.30**
	UN	178.2	OW	253.2	-47.18
	NN	236.6	OW	253.2	57.14
Total	UN	956	NN	1186	-298.30**
	UN	956	OW	1611	-592.05**
	NN	1186	OW	1611	-293.75**
		European			
Light	UN	261.4	NN	252.4	8.98
	UN	261.4	OW	617.1	-355.71**
	NN	252.4	OW	617.1	-364.69**
Total	UN	1043	NN	1307.5	-263.46*
	UN	1043	OW	1707.4	-663.42*
	NN	1308	OW	1707.4	-399.96
PAQ-C Score	UN	2.45	NN	2.80	-0.35
	UN	2.45	OW	4.06	-1.60**
	NN	2.80	OW	4.06	-1.26**

[a] Adjusted means
[b] MD = mean difference
* $p<0.05$
** $p<0.01$

Table 49. Pairwise comparisons of estimated marginal means for selected estimated energy expenditure (kcal/kg/day) and physical activity variables with significant F ratios of nutritional status for Indian and European boys.

	NS	Mean[a]	NS	Mean[a]	MD[b]
		Indian			
MVPA	UN	6.8	NN	7.4	-1.78
	UN	6.8	OW	5.6	-3.47*
	NN	7.4	OW	5.6	1.70
Total	UN	36.1	NN	37.0	2.47
	UN	36.1	OW	35.2	2.55
	NN	37.0	OW	35.2	-5.02**
		European			
Light	UN	9.1	NN	7.9	1.24
	UN	9.1	OW	16.6	-7.46**
	NN	7.9	OW	16.6	-8.70*

[a] Adjusted means
[b] MD = mean difference
* $p<0.05$
** $p<0.01$

Table 50. Regression analyses of estimated energy expenditure variables by nutritional status for the total sample.

Dependent variable	Independent variable	R^2	Beta-value[a]	β^b	F
Estimated energy expenditure (kcal/day)					
Sedentary	nutritional status	0.44	189.77	0.66	170.64**
Light	nutritional status	0.09	56.36	0.31	22.26**
MVPA	nutritional status	0.02	38.78	0.13	3.90*
Total	nutritional status	0.39	284.91	0.62	135.04**
Estimated energy expenditure (kcal/kg/day)					
MVPA	nutritional status	0.02	-1.07	-0.13	5.49*
Total	nutritional status	0.04	-1.65	-0.19	11.76**

[a]regression coefficient
[b] standardized regression coefficient
* $p<0.05$
** $p<0.01$

Research Question Five

To answer the question "Are there any race-specific differences in the growth status and physical fitness of 10 year old South African boys with different levels of energy expenditure?", the growth status and physical fitness of boys in the lowest and highest quartiles of 3-day mean MVPA and mean daily total estimated energy expenditure (kcal/kg/day) were compared with MANOVA and MANCOVA. Pairwise comparisons of estimated marginal means and Scheffé post hoc comparisons of significant MANOVAs and MANCOVAs were used. SES was used as a covariate.

The racial composition of the lowest and highest quartiles of MVPA and mean daily total estimated energy expenditure differ significantly (Chi-square statistic of χ^2 = 18.3 for 2 df, $p < 0.01$; χ^2 = 17.95 for 2 df, $p < 0.01$, respectively) (Tables 51 and 52). There are significantly more African boys in the highest quartiles of estimated energy expenditure than Indian boys. Conversely, there are significantly more Indian boys in the lowest quartiles of MVPA and mean daily total estimated energy expenditure. Thus, some of the growth and physical fitness differences between boys in the highest and lowest quartiles of estimated energy expenditure may reflect racial variation.

Race-specific differences in growth and physical fitness of boys in the lowest and highest quartiles of mean daily total estimated energy expenditure and MVPA were compared using MANOVA (Tables 53 to 58). African boys with the lowest overall habitual physical activity are taller, heavier, and have a higher BMI than the most active African boys. Similarly, Indian boys in the lowest quartile are also taller and heavier than Indian boys in the lowest quartile of mean daily total estimated energy expenditure. On the other hand, Indian boys in the lowest quartile have a smaller sitting height/stature

Table 51. Racial distribution, mean and standard deviations of estimated energy expenditure of boys in the highest and lowest categories of MVPA and mean daily total estimated energy expenditure (kcal/kg/day) for the total sample by race.

	African		Indian		European		Total	
	M	SD	M	SD	M	SD	M	SD
Total estimated energy expenditure (kcal/kg/day)								
Lowest quartile								
N	33		43		6		82	
Energy expenditure	31.8	1.9	30.6	2.5	30.2	3.0	31.1	2.4
Highest quartile								
N	57		17		8		82	
Energy expenditure	46.2	3.1	44.2	1.8	47.3	3.0	45.9	3.0
MVPA (kcal/kg/day)								
Lowest Quartile								
N	33		45		5		83	
Energy expenditure	2.4	1.0	2.5	1.0	1.6	1.6	2.4	1.0
Highest								
N	57		18		7		82	
Energy expenditure	16.2	3.3	14.9	2.2	18.0	4.2	16.0	3.3

Table 52. Chi square statistics for race differences for boys in the highest and lowest categories of MVPA and mean daily total estimated energy expenditure (kcal/kg/day).

	Total	MVPA
Highest quartile	49.78**	50.50**
Lowest quartile	26.81**	30.46**

** $p<0.01$

ratio indicating proportionally longer legs relative to stature than Indian boys in the highest quartile of mean daily total estimated energy expenditure. All other differences in growth status of African and Indian boys at the extremes of mean daily total estimated energy expenditure are not significant. There are no significant differences in the growth status or physical fitness of European boys in the highest and lowest quartiles of mean daily total estimated energy expenditure.

African boys in the lowest quartile of mean daily total estimated energy expenditure (kcal/kg/day) have greater absolute grip strength compared to African boys in the highest quartile. This, however, is a function of their larger body since grip strength per unit mass does not differ between boys at the extremes of mean daily total estimated energy expenditure (kcal/kg/day). All other growth and physical fitness differences between African boys in the highest and lowest quartiles of mean daily total estimated energy expenditure do not differ. There are no significant differences in the physical fitness of Indian boys at the extremes of mean daily total estimated energy expenditure.

There is a difference in the relationship between absolute (kcal/day) and relative estimated energy expenditure (kcal/kg/day) and growth and physical fitness (Tables 56 to 58). African boys in the lowest quartile of MVPA are heavier than African boys who are most active at high levels of estimated energy expenditure. European boys in the lowest quartile of MVPA are taller than European boys in the highest quartile of MVPA. All other differences in the growth status of African and European boys are not significant. There are no significant differences in the growth status of Indian boys at the extremes of MVPA.

African boys who are most active at high intensities complete more sit-ups in 30 seconds than to boys in the lowest quartile of MVPA. All other physical fitness differences between African boys at the extremes of MVPA are not significant. The physical fitness of Indian and European boys in the highest and lowest quartiles of MVPA do not differ.

Table 53. Means, standard deviations and F ratios for the growth status and physical fitness of African boys grouped into the highest and lowest categories of mean total daily estimated energy expenditure.

	Lowest Quartile			Highest quartile			
	Mean	SD	Md	Mean	SD	Md	F
Growth							
Stature, cm	137.3	8.2	138.5	137.0	6.0	137.1	2.13*
Mass, kg	33.8	8.3	32.1	31.7	5.4	31.0	17.31**
BMI, kg/m^2	17.8	3.5	16.7	16.8	2.3	16.7	15.91**
Proportions							
SH/ST, %	50.6	1.8	50.5	50.5	1.8	50.7	1.33
BBR, %	69.2	4.9	70.2	69.3	4.8	69.2	2.52
Body composition							
Σ of 5 SF, mm	48.0	29.2	38.3	42.4	25.7	33.7	0.00
TER, mm/mm	1.06	0.26	1.08	1.04	0.27	1.04	0.24
AMA, cm	30.5	9.5	27.3	29.2	7.9	27.7	0.04
Health-related fitness							
Sit-ups, #/30 sec	16.7	4.2	17.0	15.9	5.2	16.0	0.33
Pushups, #/30 sec	23.2	6.2	23.0	24.6	8.8	23.0	0.01
9 minute run, m	1604.9	392.4	1675.0	1544.5	335.4	1540.0	0.21
Sit and reach, cm	27.0	6.4	26.8	27.8	5.5	28.0	1.59
Performance-related fitness							
Dash, sec	9.5	1.2	9.2	9.3	1.1	9.0	0.24
Grip, kg	19.6	4.0	19.0	18.9	3.8	19.0	7.78**
Grip, kg/kg	0.6	0.1	0.6	0.6	0.1	0.6	0.30
Shuttle run, sec	22.4	2.3	21.8	23.3	2.7	22.9	0.81
Standing long jump, cm	150.3	22.2	149.5	149.1	24.1	143.0	0.62
PAQ-C Score	2.79	0.52	2.72	2.73	0.37	2.67	0.21

* $p<0.05$ ** $p<0.01$

Table 54. Means, standard deviations and F ratios for growth status and physical fitness of Indian boys grouped into the highest and lowest categories of mean total daily estimated energy expenditure.

	Lowest Quartile			Highest quartile			
	Mean	SD	Md	Mean	SD	Md	F
Growth							
Stature, cm	140.2	6.0	139.6	137.5	8.4	139.6	13.76**
Mass, kg	33.2	9.1	30.1	31.6	7.0	32.4	4.55*
BMI, kg/m^2	16.4	3.0	15.3	16.6	3.0	16.2	3.81
Proportions							
SH/ST, %	49.7	2.0	50.2	50.1	2.7	50.3	5.55*
BBR, %	68.7	6.3	68.8	70.4	4.5	70.5	0.07
Body composition							
Σ of 5 SF, mm	54.0	33.1	37.6	51.0	23.4	48.0	1.73
TER, mm/mm	1.13	0.31	1.13	1.15	0.30	1.08	0.64
AMA, cm	31.5	8.5	29.7	33.4	8.5	31.4	0.60
Health-related fitness							
Sit-ups, #/30 sec	14.5	4.9	16.0	16.9	5.3	17.0	0.36
Pushups, #/30 sec	22.8	7.0	21.5	23.6	10.3	22.0	0.91
9 minute run, m	1521.3	306.8	1524.0	1465.8	394.9	1420.0	0.12
Sit and reach, cm	23.9	6.0	24.5	23.6	6.3	24.0	2.75
Performance-related fitness							
Dash, sec	10.1	1.3	9.7	9.5	0.6	9.5	3.02
Grip, kg	18.5	3.4	18.0	18.5	3.6	20.0	0.15
Grip, kg/kg	0.6	0.1	0.6	0.6	0.1	0.6	1.19
Shuttle run, sec	23.0	2.8	22.7	24.8	3.8	24.1	0.17
Standing long jump, cm	149.8	26.4	148.0	147.3	19.0	150.0	0.02
PAQ-C Score	3.0	0.7	2.8	2.7	0.5	2.8	2.52

* $p<0.05$ ** $p<0.01$

Table 55. Means, standard deviations and F ratios for growth status and physical fitness of European boys grouped into the highest and lowest categories of mean total daily estimated energy expenditure.

	Lowest Quartile			Highest quartile			
	Mean	SD	Md	Mean	SD	Md	F
Growth							
Stature, cm	144.6	6.3	144.6	136.3	3.4	136.6	2.61
Mass, kg	34.9	5.3	33.7	32.3	3.6	32.4	0.79
BMI, kg/m^2	16.6	1.4	16.2	17.4	1.8	17.3	0.01
Proportions							
SH/ST, %	51.3	0.9	51.4	51.6	0.9	51.9	0.05
BBR, %	72.7	3.5	73.7	72.8	4.1	71.6	0.06
Body composition							
Σ of 5 SF, mm	40.0	13.3	35.5	49.2	24.5	37.3	0.03
TER, mm/mm	1.00	0.15	1.00	1.07	0.28	1.01	0.06
AMA, cm	30.9	6.6	32.2	33.1	7.8	31.4	0.03
Health-related fitness							
Sit-ups, #/30 sec	16.8	5.5	14.5	20.0	3.2	20.0	0.93
Pushups, #/30 sec	23.7	5.8	22.5	31.0	7.8	30.0	0.37
9 minute run, m	1682.5	238.0	1580.0	1788.1	306.4	1818.0	1.26
Sit and reach, cm	25.5	4.4	24.5	25.0	4.1	23.5	0.26
Performance-related fitness							
Dash, sec	9.4	0.7	9.3	9.2	0.7	9.4	0.21
Grip, kg	21.6	2.5	20.5	18.8	1.6	20.0	1.69
Grip, kg/kg	0.6	0.1	0.7	0.6	0.1	0.6	0.02
Shuttle run, sec	23.9	2.0	24.1	22.4	2.1	21.9	2.36
Standing long jump, cm	159.0	19.5	158.0	153.4	21.2	157.0	2.63
PAQ-C Score	2.6	0.3	2.6	2.8	0.7	2.6	0.29

* p<0.05 ** p<0.01

Table 56. Means, standard deviations and F ratios for growth status and physical fitness of African boys grouped into the highest and lowest categories of estimated energy expenditure in MVPA (kcal/kg/day).

	Lowest Quartile			Highest quartile			
	Mean	SD	Md	Mean	SD	Md	F
Growth							
Stature, cm	139.3	6.9	138.9	137.3	6.3	139.6	2.62
Mass, kg	35.6	7.5	34.4	31.8	5.8	31.0	4.55*
BMI, kg/m^2	18.2	3.1	17.3	16.8	2.5	16.7	2.56
Proportions							
SH/ST, %	50.4	1.7	50.5	50.5	2.0	50.6	0.46
BBR, %	68.6	5.3	68.9	69.2	4.7	69.2	0.13
Body composition							
Σ of 5 SF, mm	55.0	28.5	45.3	41.1	24.5	33.7	3.84
TER, mm/mm	1.10	0.25	1.13	1.04	0.27	1.02	1.90
AMA, cm	32.6	10.7	29.5	29.2	7.1	28.9	1.66
Health-related fitness							
Sit-ups, #/30 sec	15.8	4.0	15.5	16.0	5.3	16.0	5.14*
Pushups, #/30 sec	22.8	9.0	22.5	24.5	9.1	23.0	0.04
9 minute run, m	1600.8	366.4	1700.0	1546.6	321.4	1550.0	0.12
Sit and reach, cm	25.3	6.7	25.0	28.1	5.1	28.0	1.17
Performance-related fitness							
Dash, sec	9.7	1.4	9.5	9.3	1.0	9.0	0.96
Grip, kg	19.8	4.4	19.0	18.8	3.6	19.0	2.08
Grip, kg/kg	0.6	0.1	0.6	0.6	0.1	0.6	0.19
Shuttle run, sec	22.3	2.4	21.9	23.4	2.7	22.9	1.73
Long jump, cm	147.9	23.0	150.0	148.9	23.3	143.0	0.26
PAQ-C Score	2.8	0.5	2.7	2.8	0.4	2.7	0.20

* $p<0.05$ ** $p<0.01$

Table 57. Means, standard deviations and F ratios for growth status and physical fitness of Indian boys grouped into the highest and lowest categories of estimated energy expenditure in MVPA (kcal/kg/day).

	Lowest Quartile			Highest quartile			
	Mean	SD	Md	Mean	SD	Md	F
Growth							
Stature, cm	141.0	6.5	141.3	138.8	8.9	141.9	2.53
Mass, kg	34.9	9.2	31.7	32.5	6.8	32.9	1.09
BMI, kg/m^2	17.1	3.3	16.0	16.8	2.9	15.8	0.16
Proportions							
SH/ST, %	49.8	1.9	50.2	50.8	2.5	50.6	2.43
BBR, %	69.2	6.9	69.0	70.2	5.8	70.7	0.25
Body composition							
Σ of 5 SF, mm	60.3	36.6	42.5	49.1	22.8	46.3	0.53
TER, mm/mm	1.19	0.32	1.17	1.09	0.26	1.07	2.39
AMA, cm	31.3	8.2	29.8	34.0	12.8	28.5	0.01
Health-related fitness							
Sit-ups, #/30 sec	14.7	5.4	15.0	18.2	4.8	17.5	3.55
Pushups, #/30 sec	23.0	7.6	23.0	27.3	9.6	29.5	0.65
9 minute run, m	1565.4	287.8	1564.0	1514.3	427.5	1460.0	0.03
Sit and reach, cm	22.9	5.9	23.0	24.0	5.6	24.8	0.02
Performance-related fitness							
Dash, sec	10.3	1.4	10.0	9.7	1.3	9.5	0.04
Grip, kg	19.1	3.1	19.0	18.8	3.3	20.0	0.22
Grip, kg/kg	0.6	0.1	0.6	0.6	0.1	0.6	0.41
Shuttle run, sec	23.0	2.5	22.8	24.5	3.8	23.5	0.70
Standing long jump, cm	149.7	23.1	150.0	152.4	21.5	160.0	0.19
PAQ-C Score	3.0	0.7	2.8	2.5	0.6	2.4	3.36

* $p<0.05$ ** $p<0.01$

Table 58. Means, standard deviations and F ratios for growth status and physical fitness of European boys grouped into the highest and lowest categories of estimated energy expenditure in MVPA (kcal/kg/day).

	Lowest Quartile			Highest quartile			
	Mean	SD	Md	Mean	SD	Md	F
Growth							
Stature, cm	144.9	7.9	144.8	136.1	3.6	136.1	6.95*
Mass, kg	34.9	5.8	31.0	31.5	3.3	32.1	1.62
BMI, kg/m^2	16.6	2.0	17.5	17.0	1.6	16.5	0.18
Proportions							
SH/ST, %	51.0	1.8	51.4	51.6	1.0	51.9	0.61
BBR, %	72.1	3.8	72.7	72.9	4.4	70.8	0.11
Body composition							
Σ of 5 SF, mm	39.7	15.8	37.5	45.5	24.1	37.0	0.23
TER, mm/mm	1.10	0.19	1.02	1.02	0.27	0.95	0.33
AMA, cm	29.8	7.3	27.8	31.5	6.9	29.0	0.17
Health-related fitness							
Sit-ups, #/30 sec	16.2	6.5	14.0	19.4	2.9	20.0	1.37
Pushups, #/30 sec	22.6	7.1	19.0	30.4	8.2	26.0	2.95
9 minute run, m	1691.0	237.7	1610.0	1828.6	307.0	1890.0	0.70
Sit and reach, cm	27.0	3.1	27.0	25.6	4.0	24.0	0.44
Performance-related fitness							
Dash, sec	9.3	0.5	9.1	9.2	0.7	9.5	0.03
Grip, kg	19.8	2.3	20.0	18.6	1.7	20.0	1.02
Grip, kg/kg	0.6	0.1	0.6	0.6	0.1	0.6	0.16
Shuttle run, sec	24.3	2.6	22.8	22.5	2.2	22.1	1.63
Standing long jump, cm	150.8	12.1	151.0	151.3	22.0	148.0	0.00
PAQ-C Score	2.5	0.3	2.5	2.7	0.6	2.6	0.19

* $p<0.05$ ** $p<0.01$

Chapter 5

DISCUSSION

This study examined the relationship of SES, race and nutritional status with growth (size, proportion and body composition), physical fitness and habitual physical activity of 10 year old South African boys. The growth, physical fitness and habitual physical activity of 10 year old boys are first summarized. The discussion then focuses on growth, physical fitness and habitual physical activity with reference to SES, ethnicity and nutritional status.

Growth

Growth is addressed in terms of growth status (stature, mass), fatness (skinfolds), muscularity, and secular trends in South African populations. Variability in growth status in infancy and childhood is greater within than between races (Frongillo and Hanson, 1995), and key confounders in population variation are SES and nutritional status. This trend is evident in the present study. There are no significant race differences in growth status (stature and mass); SES accounts for 4% and nutritional status for an additional 3% of the variation in stature. On the other hand, nutritional status accounts for 58% of the variation in mass, with SES explaining an additional 2%. In general, higher SES boys within a racial group are taller and heavier compared to lower SES boys. Overweight boys are also taller and heavier than undernourished and nutritionally normal boys, and nutritionally normal boys are taller and heavier than undernourished boys.

Optimal growth is affected by a number of factors that are manifest in population diversity. Environmental factors are the primary causes of growth stunting rather than ethnicity or genetic background (Karlberg et al., 1994). Some of the factors related to linear growth retardation include poor hygiene, overcrowding and high disease loads (Karlberg et al., 1994), all of which are prevalent in South Africa at present.

Compared to U.S. reference data (Table 59), the present sample of boys is, on average, shorter and lighter, and falls between the 25th and 50th centiles. On the other hand, the present sample of boys is taller than many sub-Saharan populations, who fall between the 5th and 25th centiles of U.S. reference data for mass and stature (Eveleth, 1986, Eveleth and Tanner, 1976, 1990; Cameron, 1991). The BMI of the present sample of boys is around the 50th percentile of the U.S. reference, while the triceps skinfold is within ± 1 SD of the U.S. reference. The subscapular skinfolds of African and European boys fall within ± 1 SD of the reference, while Indian boys have larger subscapular skinfolds than the U.S. reference, which suggests proportionately greater accumulation of subcutaneous adipose tissue on the trunk.

Race and SES

While race does not account for a significant proportion of the variation in the growth status of the present sample, some of the trends are similar to those observed in previous studies of South African populations. In earlier studies, African boys were the

Table 59. Size and fatness of 10 year old South African boys compared to U.S. reference values.

	Reference data[a]			African	Indian	European	Total sample
	25	50	75	Md	Md	Md	Md
Mass, kg	31.4	34.8	39.2	31.5	30.6	33.3	31.5
Stature, cm [b]	134.0	137.0	141.5	137.9	139.0	139.2	138.4
BMI, kg/m^2	16.1	17.3	19.1	16.6	15.9	17.4	16.4
Skinfolds, mm							
Triceps	7.5	11.0	16.5	10.0	11.2	11.2	10.5
Subscapular	5.0	6.0	9.5	6.8	7.3	6.3	6.8

[a]NCHS reference values (Najjar and Rowland, 1987).
[b] Mean values are given for stature

shortest and lightest, and European boys were the tallest and heaviest (Smit and Potgieter, 1967; Richardson, 1978; Kotze et al., 1987). In the present study, European boys are the tallest and heaviest, and have the highest BMI compared to African and Indian boys. Further, the median BMI of European boys is similar to the U.S. reference median, and Indians have a BMI below the median (Figure 5). On average, African boys are shortest, while Indian boys are lightest with the lowest BMI.

Racial variation in stature have been observed in the U.S. (Krogman, 1970; Garn and Clark, 1976), England (Rona and Chinn, 1986), and Guyana (Ashcroft and Desai, 1976), where children of African ancestry are slightly taller than children of European ancestry. Trends among immigrant Indian populations in England (Rona and Chinn, 1986) and Guyana (Ashcroft and Desai, 1976), suggest that children of Indian ancestry are shorter than children of African and European ancestry.

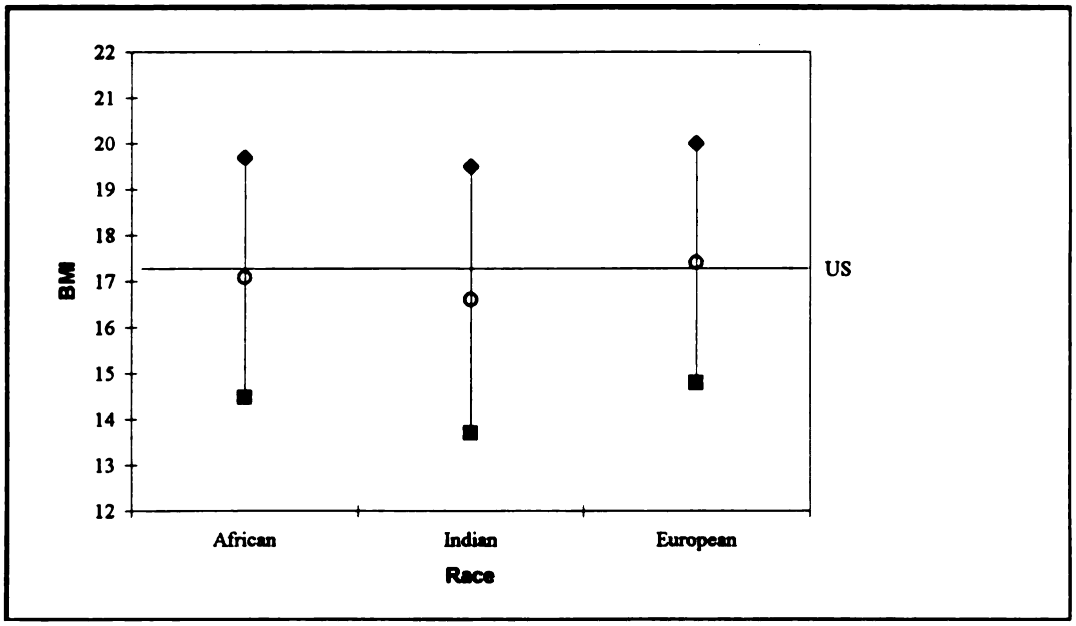

Figure 5. BMI (mean ± SD) of African, Indian and European boys compared to the U.S. reference median.

People of African ancestry in the western world are oftenmost likely of West African origin. Similarly, immigrants from the Indian subcontinent are not a homogenous group. Thus, comparisons of trends between sub-Saharan and West African populations, or people of Indian ancestry on other continents are tenuous. The mass and stature of higher and lower SES South Africa Indian boys of the current sample are similar to those of higher SES Indian boys from India (Raghavan et al., 1971), but are taller than those of two other Indian samples (Pakrasi et al., 1988; and Singh et al,. 1987) (Table 60).

Racial comparisons are confounded by SES. The short stature of sub-Saharan African boys compared to the U.S. reference may be due to the influence of environmental variables on growth potential. The tall stature of a single sample of rural African boys (Badenhorst et al., 1992), however, points out that this relationship is not unilateral. Systematic examination of the genetic and environmental matrix of South Africa, as well as their effects on attained growth is necessary.

Table 60. Mass and Stature of Indian boys from India and South Africa

		Stature			Mass	
	Median	Mean	SD	Median	Mean	SD
Indian (Raghavan et al., 1971)						
Lower SES	126.7	127.0	5.73	22.4	22.3	2.6
Higher SES	138.0	138.5	6.8	31.0	32.4	5.9
Calcutta (Pakrasi et al., 1988)		133..0	5.5	25.5		5.8
Patella City (Singh et al,. 1987)		132.6	5.9		24.1	3.1
Current sample						
Lower SES	137.6	137.6	7.0	29.3	30.5	7.0
Higher SES	139.9	139.5	6.8	31.3	33.0	7.8

In the present study, Indian boys are taller and heavier than African boys. The smaller body size of Africans compared to Indians in the present study and in the trends in earlier studies is probably a reflection of secular, SES, nutritional, and perhaps geographic variation among samples (Smit and Potgieter, 1967; Richardson, 1978, 1986; Kotze et al., 1986). However, the differences most likely reflect SES variation between Africans and Indians in South Africa.

In the present study, SES contributes differently to the variance in the mass and stature of Africa and Indian boys. SES accounts for 5% and 7% of the variation in stature and mass of African boys, respectively. On the other hand, SES does not account for any of the variation in the stature and mass of Indian boys.

The significant race difference in the overall SES ratings of the sample is due to the composition of the African, Indian and European samples (Table 61). There are proportionally more lower SES African boys compared to Indian boys, and all European boys are of higher SES. Additionally, there are differences in the SES groups. On average, lower SES Africans come from families with relatively lower incomes and less educated parents compared to lower SES Indian boys. The heads of lower SES African households, however, have greater occupational prestige compared to lower SES Indians. A possible explanation for this incongruity is that some vestiges of the apartheid era remain, and Africans are still paid less compared to others for the same job. Additionally, affirmative action may have resulted in a larger number of Africans getting jobs with better titles, but the pay is commensurate with education, training and experience. On the other hand, many Indians are traders, which is allocated an occupational prestige rating of 15. This rating is lower than that of a factory worker (21), cook (20), gardener (16), general merchandise sales assistant (21), or sales manager (69). This is probably a factor of semiotics since the term trader is used colloquially by Indians to describe all types of retail business owners and includes hawkers and informal vendors to chain store owners. The traditional use of the word trader has not been considered in the classification criteria offered by Schlemmer and Stopforth (1979).

Higher SES Indian boys come from households with a higher occupancy ratio and a lower mean education of parents compared to European boys. Higher SES African

Table 61. Indicators of SES (mean ± SD) by race for upper and lower SES.

	African	Indian	European
Lower SES			
Household Occupancy, # of people / room	1.3 ± 0.9	1.4 ± 0.7	
Education of parents, years of schooling	8.7 ± 4.6	10.4 ± 3.7	
Mid-parent income[a]	3.0 ± 1.4	3.6 ±1.3	
Occupational prestige, score	33.5 ± 16.3	27.4 ± 19.4	
SES rating	1.9 ± 0.7	1.8 ± 0.8	
Upper SES			
Household Occupancy, # of people / room	1.1 ± 0.8	1.2 ± 0.6	1.3 ± 0.8
Education of parents, years of schooling	12.8 ± 2.1	12.3 ± 1.8	13.3 ± 3.2
Mid-parent income[a]	3.9 ± 1.3	4.2 ± 1.3	4.8 ± 1.5
Occupational prestige score	67.4 ± 10.0	67.5 ± 7.0	65.0 ± 16.6
SES rating	3.8 ± 0.5	3.8 ± 0.4	3.9 ± 0.5
Overall SES	2.9 ± 1.1	3.2 ± 1.0	3.9 ± 0.5

[a] midparent income is expressed in terms of income categories (Table 16).

boys, on the other hand, come from families with the lowest mean income and European boys come from families with the highest mean income.

The relationship between sociodemographic factors and stature appears to be different for South African and Swedish children. There is a significant association between height and number of children in the family ($r = -0.60$, $p<0.01$), household density ($r = -0.52$. $p<0.01$) and occupation of the father ($r = -0.55$, $p<0.01$) of 10 year old Swedish children (Cernerud, 1993). Household density (number of people per room), number of children in the family, household number (number of people in household), and the occupation of the father are not significantly related to stature ($r = 0.03$; $r = -0.10$, $r = 0.10$; $r= 0.09$, respectively) in the present study (Table 62).

In summary, European boys are the tallest and heaviest, and African boys are the shortest and lightest, in the present study. While environmental conditions in South Africa have improved for Africans, these improvements may or may not have been adequate for Africans to attain their growth potential. The difference among racial groups in stature is most likely explained in the context of variation in SES and living conditions between groups.

Table 62. Regression analyses of stature by sociodemographic characteristics for the total sample (n=330)

Independent Variable	R^2	Beta-value[a]	β^b	F
Household number	0.00	0.02	-0.06	0.74
Occupation of parent	0.00	0.15	0.05	0.19
Household occupancy ratio	0.00	0.00	0.02	0.33
Number of children in household	0.01	0.02	-0.11	2.36

[a]regression coefficient [b] standardized regression coefficient

Nutritional status: BMI-for-age

The BMI was used as the criterion for nutritional status. The use of the BMI as an indicator of nutritional status, however, is limited. BMI is an indicator of total body fat but is a poorer estimate of percentage body fat compared to relative weight, weight /stature^3, and skinfolds (Roche et al., 1981). The correlation between BMI and percentage body fat is moderate ($r = 0.68$) in boys 6 to 12 years of age (Roche et al., 1981). Thus, some of the boys in the present sample that are classified as undernourished may, in reality, be adequately nourished small boys since the BMI probably reflects their current weight-for-height and not their nutritional history.

Based on the BMI, 24.6% of the present sample is categorized as undernourished (BMI ≤ 15th centile) and 13.7% is classified as overweight (BMI ≥ 85th centile). Proportionally more Indian boys are underweight, but only 3 of the small sample of European boys are overweight (Table 63). The BMI of Indians, on average, is lower than that of Africans and Europeans. SES variation among Indian boys affects their nutritional status. There is a higher incidence of underweight Indian boys from lower than upper SES families (50.0% vs 31.3%).

The major ethnic groups among Indians are Moslem, Gujerati, Hindi, Tamil and Telegu. Each group has different cultural practices that could potentially impact the

Table 63. Means, standard deviations, medians and ranges of the BMI by nutritional status of African, Indian and European boys

		Undernourished (≤ 15 centile)	Nutritionally normal (15th > NN < 85th)	Overweight (≥ 85th percentile)
African	Mean	14.4 ± 0.9	16.8± 1.1	22.3± 2.3
	Median	14.5	16.7	22.2
	Range	10.0-15.1	15.3-19.6	19.7-29.5
	Number (%)	38 (18.3%)	142 (68.3%)	28 (13.5%)
Indian	Mean	14.1± 0.7	16.6 ± 1.1	22.1± 2
	Median	14.3	16.2	21.7
	Range	12.6-15.1	15.2-19.6	19.6-26.6
	Number (%)	72 (45.3%)	65 (40.9%)	22 (13.8%)
European	Mean	14.1± 0.7	17.4 ± 1.3	24.1 ± 3.9
	Median	14.5	17.7	25.6
	Range	13.1-15.0	15.4-19.2	19.8-27.0
	Number (%)	7 (17.1%)	31 (75.6%)	3 (7.3%)

nutritional status of the individual, and may offer possible explanations for the polarization of BMI among the Indian boys. Peters and Ulijaszek (1992) found differences in arm circumference, and the triceps and subscapular skinfolds among children of different Indo-Mediterranean ethnic groups (Sikh, East African Hindu, Indian Hindu, Indian Moslem, Pakistani Moslem and Bangladeshi) in England. The practice of abstinence from food for prolonged periods of time is common among Moslem and Hindu children and adults, and may affect the nutritional status of individuals.

Ethnic/cultural differences among Indians are large, but were not considered in this study. An investigation of the ethnic differences and practices on nutritional status may provide insights into high prevalence of low BMIs observed among Indian boys.

Fatness

Adiposity is associated with physical activity, lifestyle variables and economic prosperity. In populations of the developing world, there is ordinarily greater adiposity among upper SES children compared to lower SES children (McGarvey et al., 1989), while this trend is often reversed in populations of developed countries, especially among females. In the present sample, there are no significant SES differences in adiposity, among boys.

SES and cultural practices affect nutritional status. Nutritional status explains a large proportion (49%) and race only for a small proportion (2%) of the variation in the accumulation of subcutaneous adipose tissue in the present sample. Overweight boys are the fattest and undernourished boys are the leanest. Additionally, Indian boys have larger accumulations of subcutaneous adipose tissue compared to African and European boys.

In the present study, Indian boys have a lower BMI, and are lighter but fatter than African and European boys. Indian boys also have greater accumulations of adipose tissue on the trunk relative to the extremities. Smit and Potgieter (1967) observed that Indians are smaller (shorter and thinner) than European boys, but have similar triceps, subscapular and abdominal skinfold thicknesses. Similar trends are observed in the present study. The apparent paradox between a lower BMI and thicker skinfolds of Indian boys was not discussed by Smit and Potgieter (1967).

The higher adiposity of Indians has also been observed in studies in Guyana. In Guyana, Indians appear to have a greater overall accumulation of subcutaneous fat regardless of their nutritional status compared to Africans (Ashcroft and Desai, 1978). Indians tend to have larger skinfolds compared to African and Europeans in the present study (Table 64).

Similar BMI-fatness relationships have been observed among Chinese populations (Wang et al., 1993; Wang et al., 1994). Both male and female of Singaporean Chinese youth (17 to 21 years of age) have a lower mean BMI but larger mean triceps skinfolds (Wang et al., 1993) compared to U.S. reference data (Najjar and Rowland, 1987). Asians in the New York City area show the same trend (Wang et al., 1994). The differences in the BMI-fatness relationship appear to be related to the population variation in relative subcutaneous fat distribution and perhaps body proportions. The results emphasize the need for care in utilizing the BMI as an indicator of nutritional status in different populations.

African boys in the present study, on the other hand, have a smaller accumulation of subcutaneous adipose tissue than Indian or European boys. Corresponding trends were observed in South Africa by Richardson (1978), who noted that African males are significantly thinner than Indian and European males, with smaller skinfolds. African boys have skinfolds that are between 16% to 24% lower than NCHS reference values

Table 64. Means and standard deviations for the BMI, skinfolds, limb circumferences and skeletal breadths of 10 year old boys from selected South African studies, by race.

	African				
	Present Study	Badenhorst (1992)[a]	Smit and Potgieter (1967)[a]	Pedi (Leary, 1968)[a]	Carey (1980)
BMI[a], kg/m²	17.1 ± 2.6		15.0		
Skinfolds					
Biceps, mm	6.6 ± 3.7	3.8 ± 1.0			
Triceps, mm	11.9 ± 5.6	6.0 ± 2.1	5.7 ± 1.2	5.2 ± 0.7	6.3 ± 2.5
Subscapular, mm	8.7 ± 5.5	4.7 ± 0.4	4.3 ± 0.8	5.2 ± 2.5	5.5 ± 2.2
Suprailiac, mm	6.9 ± 4.6	3.6 ± 0.6			
Abdominal, mm	10.8 ± 7.0	5.0 ± 0.8	3.5 ± 0.7	3.9 ± 0.6	
Σ of 2 trunk, mm	19.5 ± 12.1	9.7	7.8	9.2	
Σ of 2 extremity, mm	18.5 ± 9.0	9.8			
Σ of 5, mm	44.9 ± 24.7	23.1			
TER[b], mm	1.0 ± 0.2	0.99 [b]			
Circumferences					
Arm, cm	20.2 ± 2.5	19.0 ± 1.4	16.8 ± 1.4		
Calf, cm	27.7 ± 2.6	25.5 ± 2.1	23.3 ± 2.1		
Breadths					
Biacromial, cm	28.6 ± 2.4	27.6 ± 1.8	31.6 ± 1.8		
Bicristal, cm	19.6 ± 2.1	19.1 ± 1.2	20.8 ± 1.1		

	European			Indians	
	Present study	Smit and Potgieter (1967)[a]	Carey (1980)	Present study	Smit and Potgieter (1967)[a]
BMI[a], kg/m²	17.4 ± 2.6	16.6		16.6 ± 2.9	14.8
Skinfolds					
Triceps, mm	13.2 ± 5.9	8.9± 3.3	7.4 ± 2.5	13.1 ± 6.0	6.9 ± 1.4
Subscapular, mm	8.0 ± 5.1	5.9 ± 2.9	5.6 ± 1.7	10.3 ± 8.9	4.8 ± 0.8
Abdominal, mm	11.7 ± 7.2	6.9 ± 4.3		14.1 ± 9.5	5.8 ± 2.2
Σ of 2 trunk, mm	19.7 ± 11.8	12.8		32.7 ± 22.0	12.7
Circumference					
Arm, cm	21.0 ± 2.5	21.0 ± 3.0		20.3 ± 3.1	18.8 ± 1.0
Calf, cm	28.1 ± 2.7	28.0 ± 2.2		27.3 ± 3.1	24.6 ± 1.3
Breadths					
Biacromial, cm	29.8 ± 1.3	30.3 ± 1.7		28.6 ± 2.3	28.0 ± 1.6
Bicristal, cm	21.4 ± 1.3	22.0 ± 1.3		19.8 ± 2.1	20.1 ± 1.3

[a] BMI is calculated from means for stature and mass.
[b] The sum of 2 and 5 skinfolds, and the TER are based on means of the individual skinfolds

(Kotze et al., 1986). However, differences among individual skinfold sites are apparent. The subscapular skinfold of African boys is only slightly larger than that of European boys in the present study (Table 59). Kotze et al. (1986) also found that African boys have the smallest triceps skinfold compared to Indian and European boys, but have subscapular skinfolds that are close to reference values. The earlier South African studies did not address relative fat distribution.

Similar racial variations in subcutaneous adipose tissue have been observed in Dominica (Robson et al., 1971). In a Caribbean Island population from the Island of Dominica, poorly nourished Africans had lower triceps skinfold thickness compared to Europeans of similar nutritional status, and the triceps skinfold of Africans was 18.2% lower than WHO reference values. However, there was no difference in the thickness of the subscapular skinfold between Africans and Europeans from the Island of Dominica (Robson et al., 1971).

Compared to previous reports on South Africa populations, Africans and Indians in the present sample have larger absolute accumulations of subcutaneous fat on the trunk and extremities (Table 64). These trends are similar to those observed for Indian populations in England (Peters and Ulijaszek, 1992) and Guyana (Ashcroft and Desai, 1976). In the present sample, Europeans also have larger absolute accumulations of subcutaneous fat at all sites, compared to previous studies.

Overall, the current sample of boys is fatter than previous samples. Additionally, the arm and calf circumferences of African and Indian boys reflect the greater upper extremity subcutaneous fat. The apparent fattening of African and Indian boys may be due to the improved living conditions.

Secular Trends

Secular trends are generally characterized by an acceleration in growth and/or maturation. Positive secular change is identified by an increase in height or weight attained at given ages observed over a period of time (van Wieringen, 1986). Monitoring secular change is an important indicator of public health. The deviation of the population from the reference provides an indicator of the distance between attained and potential growth, and is based on the assumption that the reference does not change. The difference between actual and potential growth status is primarily associated with environmental variables, particularly infectious and parasitic diseases and compromised nutritional status. South Africa is characterized by a high infant mortality rate of 50 per 1 000 liveborn (Sidiropoulos et al., 1997) and an under five mortality rate of 69 per 1 000 (World Bank, 1995). There is a high rate of urbanization and a constantly high rate of migration into informal settlements in the Guateng conurbation each month (Weekly Mail, May 16, 1997). The lack of urban infrastructure, access to water, sewage facilities and garbage removal (Weekly Mail, May 16, 1997) in the informal settlements is associated with a high incidence of communicable and infectious diseases and malnutrition (Yach, 1988).

There is less variation in the stature, mass and BMI among African, Indian and European boys in the present sample compared to previous studies (Figure 6). Data from 30 to 40 years ago indicate a trend in South Africa towards increased stature in European boys over a six year period from 1958 through to 1962-1963 (Table 6). This increase in stature coincided with the beginning the South African Nationalist party rule and the enforcement of the apartheid policies of South Africa. There was a significant bias of the socioeconomic structure in favor of White South Africans (Wolpe, 1987). The greater stature of European boys likely reflects the markedly improved living conditions of Europeans during the apartheid era.

Walker and Walker (1977) reported a 5.8 cm increase in the stature and 3.0 kg increase in the mass of 10 year old African children from Letaba between 1938 and 1975, almost 40 years. Despite the increase in stature and mass, the growth status of African boys was still below the 10th percentile of the NCHS reference in 1975.

Sample means for stature, mass and the BMI of 10 year old South African boys of African, Indian and European ancestry (Smit and Potgieter, 1967; Richardson, 1978, Kotze, 1986; present study) are compared in Figure 6. The small sample (n=41) of Europeans in the present study may not be representative of the population of the greater Johannesburg area.

Between 1962-1963 and 1997, there has been an approximately 5 cm increase in stature and 6 kg increase in mass of Africans and Indians, but between 1978 and 1986, there was a decline in stature for African and Indian boys to about the levels of 1962-1963. Most of the increase in the mass of African and Indian boys and in the stature of African boys occurred after 1980. The increase in stature of Indian boys, however, appears to be more gradual, occurring over the 30 year period. Between 1967 and 1997, there has been a 1.4 cm decrease in the stature of Europeans, with the largest decrease

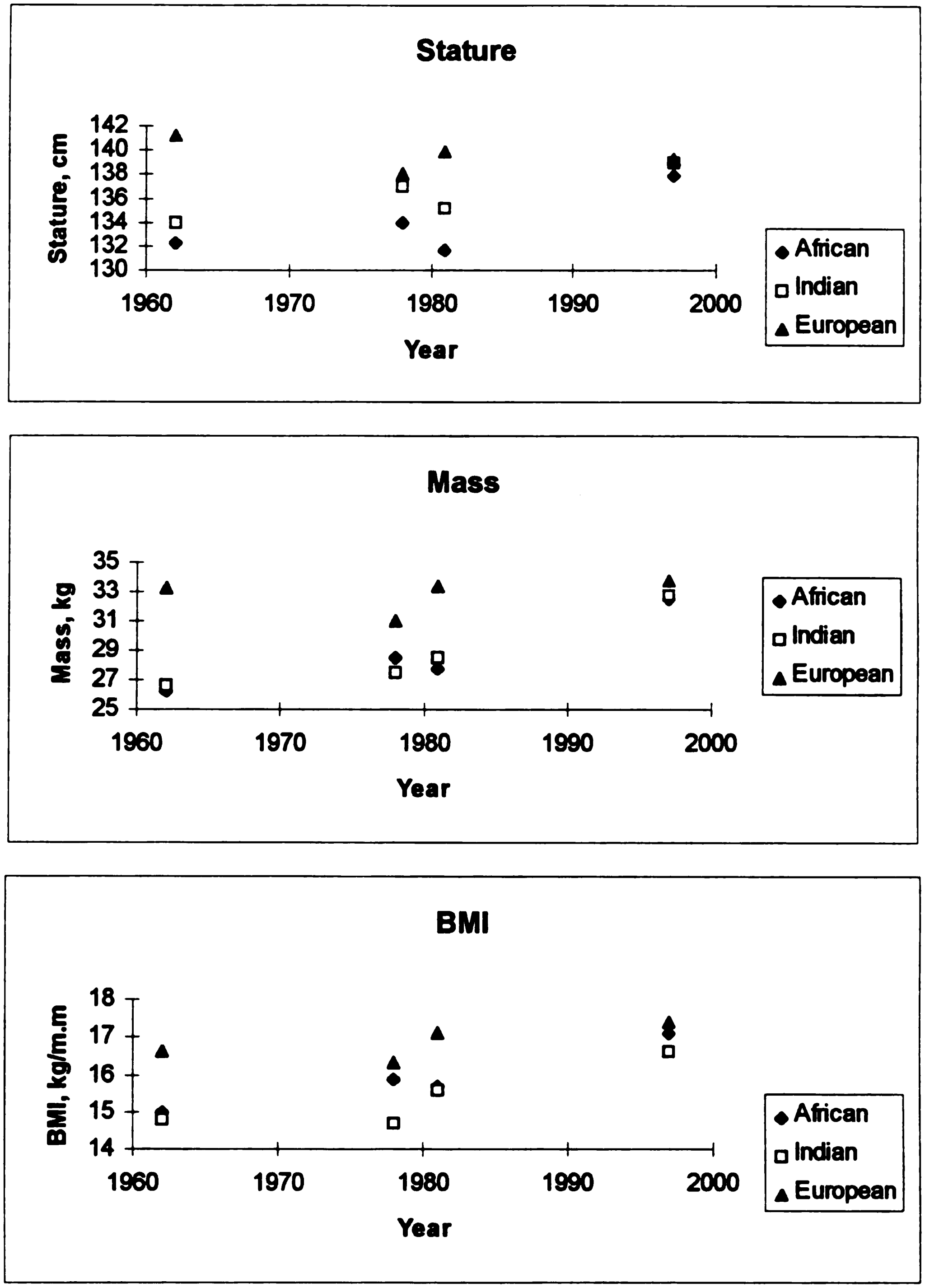

Figure 6: Stature, mass and the BMI of African, Indian and European boys in 1962-1963 (Smit et al., 1967), 1978 (Richardson, 1978), 1981 (Kotze et al., 1987) and 1997 (present study).

between 1967 and 1978. The decline in stature could be due to cohort and sampling variation. However, the political climate in South Africa became hostile following the Soweto uprising (1976) and was followed by a period of harsh repression until the late 1980s. There was stricter enforcement of influx control laws and high incidence of strikes, effectively reducing the earning capacity of the masses. The increase in both civil disturbance and the repression may have provided negative stresses on growth. Additionally, while the stature of European boys has been increasing since 1978, it is still lower than it was in 1962-1963. In contrast, the stature and mass of European boys does not differ between 1962-1963 and 1997. The gain in weight surpassed the gain in height for Africans and Indians with an increase of approximately 3 kg/m^2 in the BMI. However, the slightly higher BMI of European boys in 1997 is related to a small decrease in height relative to the previous survey. This probably reflects sampling variation, given the small number of European boys in the present study.

The positive secular changes for Africans and Indians are presumably a reflection of the social changes that have occurred during the last 20 years. However, the available data does not provide an indication as to whether the majority of the positive secular changes occurred in the post-apartheid period. There has been an increase in life expectancy, reduced infant mortality rate, increased annual growth and an increase in the overall human development index (Table 65). Improvement in living conditions and the accompanying decline in morbidity and mortality are reflected in positive secular change for Africans and Indians. The current improvements in public health with campaigns for increasing the number immunized, free mother and child medical care, and free clinics are likely to impact the growth of subsequent generations of South Africans.

Table 65. Changes in indicators of the quality of life of South Africans from 1970 to 1995.

	1970[a]	1993[a]	1995[b]
Life expectancy at birth, years			
Women	56	66	69.2
Men	50	60	62.2
Infant mortality rate per 1 000 liveborn	79	52	50.4
Average annual growth, %	1.3	2.7	
Human Development Index	1980[b]	1991[b]	
Africans	0.394	0.500	
Indians	0.655	0.836	
Europeans	0.739	0.901	
Colored	0.532	0.663	
Total	0.557	0.677	

[a] 1970 and 1993 statistics from World Bank Report (1995)
[b] 1995 statistics from Sidiropoulos et al. (1997).

Other positive environmental pressures that have occurred in the post apartheid South Africa are increased employment possibilities, the relocation of large numbers of urban and rural poor into the urban periphery, increasing access to public health services and employment, and a more varied diet. Conversely, the crowding in peri-urban squatter settlements, the lack of running water and sanitation facilities, and removal of human and other waste exert negative environmental pressures on these populations. However, the living conditions in the peri-urban squatter settlements are relatively better than those in rural areas and possibly account for the positive secular changes observed in the stature and mass of African boys. The environmental changes and pressures that are taking place in the dynamic social structure of South Africa needs to be systematically addressed within the context and history of the lives of the individuals.

A corollary of the improved living conditions is the increase in the BMI of 10 year old African (2.1 kg/m^2), Indian (1.8 kg/m^2) and European (0.8 kg/m^2) South African boys compared to boys 35 years ago. African boys have the greatest increase in the mean BMI. The increase in BMI is resulting in a higher proportion of the South Africans being classified as obese. Obesity is a risk factor for many cancers and coronary heart disease (Must et al., 1992), as well as the metabolic cascade that results in type II diabetes (Reaven, 1988). Additionally, Indian boys have significantly higher accumulations metabolically active subcutaneous adipose tissue on trunk which poses major health risks. The change in the nutritional and growth status of the South African population may have some implications on the health-related fitness of the population.

Physical Fitness

AAHPERD and NCYFS reference values were used for the comparison of some fitness items (50 meter dash; 9 minute run, sit and reach). Other items (standing long jump, grip strength) were compared to available data on 10 year old boys from South Africa, the U.S., and Mexico (Table 66). Reference data for the 100 meter shuttle run, 30-second sit-ups and 30-second push-ups for Belgian boys (Beunen et al., 1988) are not available for 10 year old boys. Further, comparative data on the performances of 10 year old South African boys are apparently not available. Comparisons for African, Indian and European boys were made separately.

Variation in health- and performance-related fitness of boys in the present study was examined in the context of race, SES and nutritional status. SES and nutritional status do not contribute to the variation in the push-ups, distance run, and sit and reach.

Table 66. Summary of means (SD, where available) for physical fitness of 10 year old boys from selected studies.

	Dash, m/sec	Grip, kg[a]	Standing long jump, cm	9-min run, m	Push-ups[b],	Sit and reach, cm	Sit-ups[cd]
Present Study							
African	5.3	19.3	150.5	1617	23.7	27.8	16.4
		(3.6)	(21.5)	(360.5)	(8.2)	(5.7)	(5.3)
Indian	5.1	18.6	149.8	1556	25.2	24.0	16.5
		(3.4)	(21.9)	(336.9)	(8.3)	(5.9)	(5.9)
European	5.3	19.3	157.7	1875	28.0	25.7	17.2
		(3)	(21.9)	(471.6)	(8.0)	(5.4)	(5.5)
South Africa							
Smit (1968)[c]							
Indians			123.1		29.7		18.3
			(16.4)		(10.7)		(5.8)
Colored			138.7		41.6		23.8
			(18.5)		(15.6)		(8.0)
U.S.							
Clarke (1976)	5.6		150.0	1570			24.0
AAHPERD (1984)			152.0	1545		25.0	34.0
Slaughter and Lohman (1982)	5.4		147.0				
	(0.7)		(21.0)				
Haubenstricker and Seefeldt (1986)	6.2		153.0				
NCYFS (1995)						34.3	34
Malina and Roche (1983)							
Combined		22.5					
Black	5.6		156.0				
White	5.4		144.0				
Other countries							
Benefice and Malina (1996) - Senegalese	4.3		137.0				
	(0.3)		(0.2)				
Malina et al. (1991) - Mexican		13.5					
		(3.2)					
Malina and Buschang (1985)	4.7	15.0	120				
		(2.4)	(10.4)				

[a] Different dynamometers were used to measure grip strength in each study
[b] 30 second push-ups in the present study, 60-second push ups for other studies
[c] 30 second sit-ups in the present study, 60-second push ups for other studies
[d] Sit-ups to exhaustion

Race accounts for 3%, 2% and 5%, of the variation in these items, respectively. Nutritional status accounts for only 1% of the variation in the dash, 11% of the variation in absolute grip strength (kg), and 22% of the variation in grip strength per unit mass (kg/kg). SES accounts for an additional 2% of the variation in the absolute grip strength (kg), while race accounts for an additional 1% of the variation in relative grip strength (kg/kg).

Other factors thus influence health-and performance-related fitness. Performance on fitness tests is affected by past experiences in activity and fitness testing. Sit-up and push-up performances often are a result of practice and familiarity with the activity. Similarly, the agility demonstrated on the shuttle run may be affected by practice. Many children perform poorly on these items because they do not have previous experiences with such standardized tests.

Most of the studies used in the comparisons grouped subjects from 10.0 to 10.9 years of age. The grouping by age, however, was not specified in several studies (Smit, 1967; Benefice and Malina, 1996), and 10 years of age was interpreted as a mean age of 10.5 years. Estimated speed (m/sec) on the 50 meter dash was compared to performance on the 50 yard and 35 yard dashes, after adjusting for meters and yards. Overall, the present sample of boys has a running speed that is slower than those reported in studies on U.S. samples. The performance of African and European boys on the distance run is better than the median performance of U.S. boys, but that of Indian boys is slightly lower compared to U.S. boys. Comparison of grip strength is confounded by testing apparatus. The Martin manometer (Benefice and Malina, 1996), Narragansett dynomometer (Malina and Roche, 1983), and the Stoelting adjustable dynamometer (Malina et al., 1991, present study) are examples. With these limitations, the grip strength of the current sample is lower than that of the U.S. comparative values.

Push-ups and sit-ups scores could not be compared directly with those in the literature because 30-second sit-ups and push-ups tests were used in the current study and the 60-second sit-ups and push-ups tests were used in the comparative studies . Performance on the 60-second sit-ups and push-ups are not equal to twice that of the 30-second sit-ups and push-ups, respectively, since fatigue is a potential limiting factor. Nonetheless, the 30-second push-ups and sit-ups scores in the current study are close to those previously reported for Indians (Smit, 1968) on the 60-second push-ups and sit-ups, suggesting better performances on these items by the current sample of Indian boys.

Comparisons indicate that American Black children have better performances on the dash (Hutinger, 1959; Milne et al., 1976; Malina and Roche, 1983) and standing long jump (Milne et al., 1976). In earlier studies of older South African boys, however, Africans did not have a performance advantage (Table 9). Europeans had the best, and Africans had the poorest, performances on all items compared - sit-ups, shuttle run, standing long jump, 50 yard dash, and distance run (Sloan, 1966).

Despite the low association between race and physical fitness, there are race differences in fitness in the present study. Europeans have the best performances on all items except on the sit and reach, with mean performances on the standing long jump and distance run that surpass the 50th centile of AAHPERD norms. There are no differences in the performance of Africans and Europeans on the dash and absolute grip strength.

Africans have better performances on the sit and reach and greater grip strength per unit mass (kg/kg) compared to European and Indian boys. Indians have the lowest scores on most physical fitness test items (dash, grip, distance run, shuttle run, sit and reach and standing long jump), with Africans having the lowest scores only for the sit-ups and pushups. Trends in physical fitness associated with race are similar to those reported by Goslin and Burden (1986) for African and European South African boys (16 to 18 years of age).

The low physical fitness of Indians relative to African, European and "Colored" South Africans has been previously reported (Smit et al., 1968). The higher ranking of the physical performance of the combined Indian-"Colored" group compared to Africans reported by Sloan (1966) could be due to the better performances of "Coloreds".

The flexibility of the lower back and upper thighs of African and European boys in the current sample is above the median, with Indian boys having performances slightly below the 50th percentile of the AAPHERD (1984) reference values. The sample of boys included in the NCYFS study, however, have better performances on the same sit and reach test than the current sample (Table 66). Both African and European boys have greater endurance on the distance run compared to U.S. samples (AAPHERD, 1984; Clarke, 1976). Explosive strength on the standing long jump in the present study falls within the range of means reported in the U.S., with European boys jumping further than the U.S. mean.

The present sample of African boys have better performances on physical fitness tests compared to those of Sloan (1966). In addition to sampling differences, the differences in fitness may be due to changes in SES and nutritional status over the last 30 years. The change in the hegemony and political economy of the country in the 1990s resulted in a shift in the interrelationship of race, SES, and nutritional status. Other factors, such as rearing conditions, health status, habitual physical activity, the opportunity to practice skills, and greater involvement in organized sport could be significant determinants of physical performance.

If the U.S. reference medians (AAHPERD, 1984; NCHS, 1987) are used as the cut-off point for specific fitness tests, South African boys score above the median for cardiorespiratory endurance and lower back flexibility (Table 67). Skinfold thicknesses are comparable, allowing for measurement variation and different calipers.

Table 67. Comparison of fatness and selected performance items of present study relative to AAHPERD (1980) percentiles by race for higher SES boys and the total sample[abc].

	Present Study				AAPHERD
	African	Indian	European	Total sample	Median
BMI[b]	16.9 (16.6)	16.1 (15.9)	17.4	16.9	17.3
Distance run, m	1621 (1617)	1513 (1556)	1875	1622	1545
Sit and reach, cm	27.3 (27.8)	24.1 (24.0)	25.7	26.2	25
Standing long jump, cm	151.1 (150.5)	150.6 (149.8)	157.7	151.1	152.0
Skinfolds, mm					
Subscapular[b]	7.0 (6.8)	7.6 (7.3)	6.3	6.8	6.0
Triceps[b]	10.8 (10.0)	12.2 (11.2)	11.2	10.5	11.0

[a] Total sample values are indicated in brackets.
[b] NCHS reference data (Najjar and Rowland, 1987).
[c] Medians are used for measures of fatness (BMI and skinfolds), and means are used for performance

Health-related physical fitness as indicated in the distance run, sit and reach, and subcutaneous adipose tissue at the subscapular and triceps sites of the current sample differs by race. Indian boys have a lower median BMI compared to the AAPHERD reference, but have slightly thicker skinfolds at the triceps (12.2 vs 11.0 mm) and subscapular (7.7 vs 6.0 mm) sites. Thus, the present sample of Indian boys has slightly more subcutaneous fat but a lower BMI than the reference population. This trend of large accumulations of subcutaneous adipose tissue and low BMIs has not been observed in earlier South African studies, but has been found in Asian populations (Wang et al. 1993; Wang et al., 1994). The higher subcutaneous fat with a lower BMI in the present sample may be indicative of higher adiposity among the current sample. Additionally, they have poorer performance on the distance run and the sit and reach tests compared to U.S. boys.

African boys also have a lower BMI and a slightly thicker subcutaneous fat depot at the subscapular (7.0 vs 6.0 mm) site compared to the AAPHERD reference. However, African males have better endurance on the distance run and greater flexibility of the lower back compared to the reference. European boys, on the other hand, do not differ significantly from U.S. boys in the BMI or subcutaneous adipose tissue, but perform better on the distance run and standing long jump than the AAPHERD references.

Fatness and fitness

The relationship between fatness and fitness is not clear for the present sample of boys. There is evidence to indicate that the fatness of an individual affects his/her performance on physical fitness items. On one hand, fatness has a negative impact on performances in which the body has to be projected through space such as the standing long jump and dash (Malina, 1975; Malina, 1994). On the other hand, overweight children are stronger on tests of absolute strength (Beunen et al., 1983). Alternately, underweight individuals have poorer performances in absolute grip strength (Malina, 1984). In the present study, race appears to affect the relationship between fatness and fitness.

The relationship between fatness and fitness of the present sample of boys was further examined using stepwise regression analyses. Regression analyses for the total sample, and separate analyses by race of fatness (sum of five skinfolds) and the BMI on physical fitness variables were performed (Tables 68 to 71). Total fatness explains a small proportion of the variation in the dash (5%), distance run (5%), push-up (1%), sit and reach (2%), sit-ups (4%) and standing long jump (2%) performances in the total sample. On the other hand, total fatness accounts for 31% of the variation in grip strength per unit mass. The BMI also accounts for some of the variation in grip strength per unit mass (2%), the sit and reach (8%), and standing long jump (3%).

The relationship between fatness and physical fitness differs across race groups, and there are no clear patterns between regional accumulation of subcutaneous adipose tissue and physical fitness (Tables 68 to 71). Fatness explains a fraction of the variation for only three of the eight physical fitness items in European boys, ranging from 12% to 38%. In contrast, some of the variation in the performance of African and Indian boys on 6 of the 8 fitness items can be explained in part by fatness. Fatness accounts for 2% to 27% and 3% to 41% of the variation in physical fitness of African and Indian boys, respectively. Variation in fatness explains a large proportion (27% to 41%) of the variation in grip strength per unit mass. With the exception of grip strength, these trends are consistent with those of Belgian boys, 12 to 20 years of age, who showed a negative association between fatness and a variety of motor performances (Beunen et al., 1983).

Fatness was positively associated with static strength and absolute grip strength of boys in the present study. However, relative grip strength (expressed per unit body weight) was negatively associated with fatness, possibly pointing to a proportionally greater contribution of inert fat tissue per unit mass for fatter boys compared to thinner boys.

There is a negative association between performance on physical fitness tests and fatness of African and Indian boys on all items except absolute grip strength (Tables 68 to 71). However, when expressed per unit body mass, the association between fatness and grip strength is negative. Similar fatness and physical fitness associations are evident for European boys on grip strength per unit mass and the nine minute run.

SES variation in physical fitness

One of the confounding factors in estimating the influence of SES on physical fitness is that SES is often related to nutritional status. There is, however, considerable evidence that points to poorer physical fitness in lower, compared to upper, SES boys in developing countries (Desai et al., 1984; Ghesquieré and Eeckels, 1984; Perez et al., 1991; Henneberg and Louw, 1998). Perez et al. (1991) reported that upper SES children have better performances on the 12 minute run, 50 meter dash and vertical jump compared to lower SES Argentinean children. The differences were attributed to upper SES children having greater access to organized sport and equipment, and earlier involvement in both sport activities and spectator sport (Perez et al., 1991). On the other hand, some researchers (Ponthieux and Barker 1965) found no significant SES variation in physical performance of fifth and sixth grade boys and girls in the U.S. There were no

Table 68. Coefficients of the regression of the BMI and fatness on physical fitness variables for the total sample of South African boys (n=378).

Independent Variable	Dependent variable	R^2	B-Value[a]	Beta[b]	F
Dash, sec	Σ of 5	0.05	-0.01	-0.22	17.75**
Grip, kg	BMI	0.14	0.46	0.37	56.40**
	BMI and	0.16	0.78	0.63	35.24**
	Σ of 5		-0.04	-0.31	
Grip, kg/kg	Σ of 5	0.31	0.00	-0.56	161.47**
	Σ of 5 and	0.33	-0.00	-0.36	86.81**
	BMI		-0.01	-0.23	
9 minute run, m	Σ of 5	0.05	-2.95	0.22	17.50**
Push-ups, #/30 sec	Σ of 5	0.01	-0.03	-0.10	3.87*
Sit and reach, cm	Σ of 5	0.02	-0.03	-0.14	6.98**
	Σ of 5 and	0.10	-0.12	-0.56	19.27**
	BMI		1.11	0.51	
Sit-ups, #/30 sec	Σ of 5	0.04	-0.04	-0.20	15.52**
Standing long jump, cm	Σ of 5	0.02	-0.12	-0.16	8.82**
	Σ of 5 and	0.05	-0.32	-0.41	9.69**
	BMI		2.39	-0.30	

Note: Signs for the dash are inverted.
[a]regression coefficient [b] standardized regression coefficient

Table 69. Coefficients of the regression of the BMI and fatness on physical fitness variables for African boys (n=188).

Independent Variable	Dependent variable	R^2	B-Value[a]	Beta[b]	F
Grip, kg	BMI	0.11	0.45	0.33	23.14**
	BMI and	0.14	0.83	0.60	15.27**
	Σ of 5		-0.05	-0.32	
Grip, kg/kg	BMI	0.25	-0.02	-0.50	63.65**
	BMI and	0.27	-0.01	-0.29	34.98**
	Σ of 5		0.00	-0.26	
9 minute run, m	Σ of 5	0.04	-2.80	-0.20	7.71**
Push-ups, #/30 sec	Σ of 5	0.02	-0.05	-0.15	4.25*
Sit-ups, #/30 sec	Σ of 5	0.03	-0.03	-0.16	5.04*
Standing long jump, cm	Σ of 5	0.03	-0.15	-0.18	6.31*

Note: Signs for the dash are inverted.
[a]regression coefficient [b] standardized regression coefficient

Table 70. Coefficients of the regression of BMI and fatness on selected[a] physical fitness items for Indian boys (n=130).

Independent Variable	Dependent variable	R^2	B-Value[b]	Beta[c]	F
Dash, sec	Σ of 5	0.12	-0.01	-0.00	17.04**
Grip, kg	BMI	0.21	0.53	0.46	33.93**
Grip, kg/kg	Σ of 5	0.41	-0.00	-0.64	91.06**
9 minute run, m	BMI	0.03	-21.24	-0.18	4.47*
Sit-ups, #/30 sec	Σ of 5	0.14	-0.04	-0.38	21.76**

Note: Signs for the dash are inverted.
[a] only variables which had a relationship are included
[b] regression coefficient [c] standardized regression coefficient

Table 71. Coefficients of regression of the BMI and fatness on selected[a] physical fitness items for European boys (n=40).

Independent Variable	Dependent variable	R^2	B-Value[b]	Beta[c]	F
Grip, kg/kg	BMI	0.38	-0.02	-0.62	24.15**
9 minute run, m	Σ of 5	0.17	-7.61	-0.41	7.78**
Sit-ups, #/30 sec	Σ of 5	0.12	0.07	0.35	5.28*

[a] only variables which had a relationship are included
[b] regression coefficient [c] standardized regression coefficient

clear SES trends in fitness in the present study, even when the effects of race, and both race and nutritional status were controlled. SES was quantified differently in the present study than in the Argentinean study. In the latter study, SES classification was made on the basis of the area of residence, classified as lower and upper SES. Cultural and environmental variables of the shared environment are possible confounders in the fitness differences observed between upper and lower SES Argentinean boys, and may not be a true reflection of SES differences in fitness. Further, in the present study the effects of SES on physical fitness differed by race. Higher SES African boys had better performances on more physical fitness test items compared to lower SES boys. On the other hand, lower SES Indian boys had better performances on more physical fitness items compared to higher SES boys. Factors that may confound the relationship between physical fitness and SES are rearing and parental supervision (Malina, 1988), among others.

Nutritional status and physical fitness

Nutritional status is a significant factor affecting physical work capacity and performance (Satyanarayana et al., 1979; Desai et al., 1984; Malina and Buschang, 1985; Malina and Little, 1985; Malina, 1985). In the present study, grip strength varied most with nutritional status. Absolute grip strength was greatest in overweight boys, but when body mass was accounted for, undernourished boys had significantly greater grip strength per unit body mass, regardless of race. These results are consistent with other findings (Ghesequieré and Eeckels, 1984; Malina and Buschang, 1985). The larger body size of overweight boys was also negatively related to physical fitness. Overweight boys completed fewer sit-ups and ran a shorter distance in nine minutes compared to nutritionally normal and undernourished boys. Undernourished boys had superior fitness on these items compared to nutritionally normal and overweight boys

There is variation in relationships between nutritional status and fitness within racial groups. Undernourished African boys ran the shortest distance in nine minutes compared to nutritionally normal and overweight African boys. Undernourished Indian boys, on the other hand, ran a longer distance in nine minutes compared to nutritionally normal or overweight Indian boys. Undernourished Indian boys, however, had significantly larger estimated arm muscle area per kilogram body weight than nutritionally normal or overweight Indian boys. Assuming that estimated arm muscle reflects the proportion of muscle mass to body weight, this may contribute to the better distance run performances. On the other hand, the difference in arm muscle could be an artifact of measurement error and derivation of arm muscle.

Habitual physical activity and physical fitness

Data on the activity patterns and estimated energy expenditure of South African children are limited. Estimated energy expenditure in the present study is compared to other populations of similar age in Table 72. The comparative data for estimated energy expenditure are based on heart rate monitoring, doubly labeled water, and recall surveys. Each of the estimates has a reasonable degree of error. Of these methods, doubly labeled water is the most reliable and has an accuracy of between 90% to 95% of that measured by indirect calorimetry (Schoeller, 1988). Heart rate monitoring is based on estimations of energy expenditure from heart rates. However, this method does not discriminate between activity and non-activity (i.e., stress, fatigue, and environmental factors among others that may elevate heart rate) heart rates. Thus, estimates based on heart rate monitoring may overestimate habitual physical activity.

The energy expenditure of Senegalese children (Benefice, 1993) was estimated from observations of physical activity over four two-day periods in which subjects were observed for six hours each day. Since the activity was recorded by an observer, there was greater accuracy of reported physical activity compared to the present study. Similar values were used to estimate the energy cost of activities in all categories except for hard intense physical activity, category nine. Benefice (1993) assigned a lower median energy

Table 72 Summary of studies of physical activity and estimated energy expenditure of children.

Study	Sample	Physical Activity Measurements				
		Sedentary	Light	MVPA		
Senegalese children (12 yrs)	Rural children	12.3 hours	10.1 hours	1.3 hours		
Observations (n=20)						
(Benefice, 1993)						
Present study	Urban children	20.1 hours	2.6 hours	1.4 hours		
Bouchard protocol						
		Physical Activity	MVPA			
Irish (7, 9 12 and 15 yrs). (Livingstone et al., 1992)	Younger children (7-9 years of age)	474 mins/day	91 mins/day			
Doubly labeled water and heart-rate monitoring (n= 19 boys)	Older children (12 and 15)	282 mins/day	52 mins/day			
Present Study		240 mins/day[b]	84 mins/day			
		Energy expenditure in activity	Total daily energy expenditure			
Colombian (Spurr and Reina, 1988)	Undernourished	669 kcal/day	1852 kcal/day			
(10 – 12 yrs)						
Heart rate monitoring	Nutritionally normal	304 kcal/day	2017 kcal/day			
Present study		729 kcal/day	1256 kcal/day			
		sleep	sed	light	MVPA	kcal/kg/day
Torun et al. (1996)[a]		time in hours				
(10 – 14 yrs)	Developing urban	8.5	7.5	4.0	4.0	53.2
meta-analysis of 3 studies	Industrial urban	10.5	5.5	4.5	3.5	56.3
Present study	Developing urban	9.7	10.4	2.6	1.4	38.5

Note: [a] Samples not indicated

[b] Includes light and MVPA

cost for hard intense physical activity of 7 METS versus 7.8 METS assigned by Bouchard et al. (1993) that was used in the present study.

The present sample of children spend considerably more time on sedentary and less time on light activities compared to rural Senegalese children (Benefice, 1993) and children in developing and industrial communities (Torun et al., 1996). Rural Senegalese children do not attend school whereas the boys in the present sample spend an average of 6 hours a day at school. The current sample of South African boys engages in more MVPA than undernourished Senegalese boys, but less than reported for Irish boys (Livingstone et al., 1992).

Total estimated energy expenditure is lower in the present sample compared to other data (Table 72) on the basis of estimates of kcal/day (Spurr, 1988) or kcal/kg/day (Torun et al., 1996). Heart rate recordings were used to estimate the energy expenditure of the Colombian children. Thus, energy expenditure was less subjective despite the lack of discrimination between physical activity and physiological states.

The FAO/WHO/UNU (1985) recommendation for estimated energy intake is 237 kJ/kg/day (56.7 kcal/kg/day), which is approximately 1843 kcal/kg/day for the present sample of boys (mean weight of 32.5 kg). This sample of boys has a mean estimated energy expenditure of 1255.8 kcal/day or 38.5 kcal/kg/day. The energy intake of the current sample was not estimated, but the estimated energy expenditure of the current sample of boys is low. This may be due to the use of the 3-day protocol and the ability of the boys to complete the diary.

The reliability of recall surveys is related to the competence of the individual to complete the survey accurately. Cultural differences change the reliability of this technique across populations. Furthermore, activities at the highest intensity levels were the most reliably recalled on the Bouchard protocol, in both the current study and the study of Canadian youth and adults (Bouchard et al., 1983). These methodological differences and limitations are inherent in the reported estimates.

In the present study, energy expenditure was estimated from a recall survey using the protocol of Bouchard et al. (1983). Since the accuracy of the recall is dependent upon the ability of the child to recall and record the activity of the preceding 24 hours and to have a well developed sense of time, the accuracy of the recall may be low. In the present study, there is a high association between activity records for lunch and recess and direct observation (r=0.86), which is similar to that reported by Bouchard et al. (1983).

The culture of the present South African sample may perhaps play a major role in the accuracy of recording the data and may be a possible explanation for the low estimated energy expenditure. Understanding the concept of time and being able to provide reasonable estimates of the duration of activities is bound by the culture of chronological time. Most subjects in the present sample did not wear watches and had no means by which to make reasonable estimations of the time that they spent in activities. Furthermore, subjects (n=57) reported higher levels of physical activity during lunch and recess compared to observations, but this again may be due to an inability to estimate the duration of the activity, and is consistent with other data. There is a tendency for children to exaggerate the amount of time spent in MVPA (Baranowski et al., 1982; Bouchard et al., 1983). Additionally, the inability of subjects to recall all activities that they had engaged in over the preceding 24 hours is a limitation. The recall questionnaire was developed and validated on a sample of Canadians who may have had a better developed concept of chronological time compared to the present sample of boys. The low estimated energy expenditure of the current sample may be due to methodological limitations and the inappropriateness of the measurement tool on this sample of boys.

Physical activity is also affected by interpersonal, physical and social environments, and public policy and interactions among these variables (McLeroy et al., 1988; Sallis et al., 1997; King et al., 1995; Sallis and Owen, 1997). Environments rich in resources such as sidewalks, parks, exercise facilities and health clubs make it easier for people to be physically active (Sallis et al., 1997). Most South African residential areas do not have environments that are conducive to physical activity, and are possible reasons for the lower estimated energy expenditure.

The greater Johannesburg area is characterized by small homes and yards, crowding, high crime rates, and a lack of parks and recreation facilities. These factors limit physical activity. Additionally, both organized and petty crime are high in South Africa and there is a general fear for the safety of self. Children in environments that have high rates of crime, poverty and crowding engage in higher levels of sedentary activity (Sallis, 1993; Goodway, 1994). Goodway (1994) found that Flint inner city children in an environment with high crime, unemployment, small housing conditions, and poverty engaged in predominantly sedentary indoor activities and had little or no exposure to physical activity outside of school. Poor communities that have few resources are less able to provide recreation and activity resources than more affluent ones. Streets and the playgrounds of poor at-risk communities are often not safe places in which to exercise or play.

Most of the government schools and the two private schools in this sample had limited play ground areas. Two of the schools visited had play fields with an area less than 100 square meters and no indoor facilities. The model-C schools had large playing areas and significantly more sport equipment available for recreational purposes. The majority of the Government schools had large grounds but lacked facilities and equipment for physical activity.

An additional mitigating factor for low levels of physical activity in the current study is the unusually cold and rainy autumn season in 1997. Physical activity of U.S. children is lower in fall and winter than in summer and spring (Ross et al., 1985; Baranowski et al., 1993). Ross et al. (1985) reported that winter activity levels were 47% that of summer levels. Since most schools and communities do not have indoor sport and recreation facilities, this restricts the possibilities of physical activity in inclement weather conditions. Additionally, if schools have halls or gyms, they are often used for table tennis and this limits the number of people that could be involved in the activity. Overall, there is limited space for children to play in, contributing to a reduction in physical activity, and there is a significant relationship between the greater availability of play spaces and higher activity levels in children (Sallis et al., 1993).

Lifestyle factors such as television viewing and time spent in commuting affect physical activity. African children had an average commute of 1.4 hours a day. This commute added to the school day of 6 to 6.5 hours, decreased the amount of time available for physical activity. Furthermore, most African children traveled back and forth on taxis, which are informally run shuttle services and are very unpredictable. Children often have to wait for over an hour for the taxi to drop-off the first load of children and return for the next load. The fear of missing the taxi causes children to mill around the pick-up point waiting for the taxi's return.

Many Indian children spend between 2.5 to 3.5 hours at vernacular (Indian language and religious) schools in the afternoon, in addition to their regular school day. Many European boys and upper SES African and Indian boys go to after-school care programs until 5:30 or 6:00 p.m. After school care programs provide supervised environments in which children complete their homework or read silently. Thus, in addition to the 6 hours spent in school, the current sample of boys probably spent an additional 2 hours a day in sedentary activity. This accounted for approximately 18 hours of the day since an average of 10 hours a day were spent sleeping.

In the present study, time spent in television viewing and computer games combined were 2.3, 2.7, and 2.0 hours for African, Indian and European boys, respectively, and surpass the 2 hour maximum advocated by Bungum and Vincent (1997). Bungum and Vincent (1997) found that television viewing of more than 2 hours a day was negatively associated with physical activity. In the present study, there were moderate negative correlations (-0.38, -0.40 and -0.30) between time spent on TV and games, with sedentary, light and moderate physical activity, respectively. There is a high moderate ($r = -0.65$) negative correlation between time spent on TV and games and total energy expenditure, which does not change when the effects of race, SES and nutritional status are partialled out. Additionally, there appears to be no significant correlation between the sum of skinfolds and BMI with television viewing ($r = -0.01$; and $r = 0.00$; $p>0.10$), even when the effects of SES, race and nutritional status are removed statistically.

The correlations between television viewing and estimated energy expenditure and fatness are lower than those for a sample of 9-12 year old Canadian boys from Quebec (Katzmarzyk, et al., 1998). The correlation between TV and MVPA and total energy expenditure were -0.13, and -0.12, respectively in Quebec boys. The correlations between the sum of skinfolds and BMI were also low, -0.17 and 0.17, but significant. The amount of time spent in television viewing for Canadian boys thus has a weak association with indicators of physical activity and health-related fitness.

The difference in the association between television viewing and energy expenditure and health-related fitness of the Canadian and South African samples may be due to lifestyle factors. South African boys watched more television (2.7 ± 1.6 hours per day) than the Canadian boys (2.0 ± 0.9 hours per day). Furthermore, the negative association between television viewing and estimated energy expenditure may have a threshold effect, with a greater association after 2 hours or more of television viewing. The limitations in the methodology employed to estimate energy expenditure and the time spent watching television may also affect the association between television viewing and energy expenditure, and health-related fitness.

Attitudes surrounding sport and sport participation are largely socialized. Leonard (1982) identifies the school, peer group, community and mass media as some of the external agents of sports socialization. The mother, however, provides a greater influence on the sport socialization of children (Baranowski et al., 1992). The role of the school as a socializing influence is of particular importance in South Africa since there is an absence of organized sport most schools. Also, some of the schools do not have PE teachers and this reduces the opportunities for the school to provide the basic physical activity skills and the development of physically active lifestyles. There is a need to better understand the relationship between the environmental factors on the physical activity levels of individuals. The effects of crime, crowding and lack of public spaces on the physical activity patterns of children needs to be identified before plans to increase activity levels can be implemented.

Habitual physical activity patterns of the subjects were also assessed using the Physical Activity Questionnaire for Children (PAQ-C). There are no significant race, SES or nutritional status differences in the PAQ-C scores. Multiple regression analyses of the PAQ-C score on the physical fitness variables were also done (Table 73). Additionally, to assess the effects of self-rated habitual physical activity during particular segments of the day, multiple regression analyses of the habitual physical activity variables of self-rated levels of activity during the physical education class, recess, lunch, evenings and afterschool on physical fitness were done (Table 74).

Table 73. Regression analyses of reported 7-day habitual physical activity (PAQ-C score) on selected physical fitness variables by race.

Dependent variable	R^2	B-value[a]	β^b	F
		African		
Sit-ups	0.05	2.53	0.23	6.60*
		Indians		
Push-ups	0.06	-4.0	0.25	4.50*

*p<0.05 **p< 0.01
[a]regression coefficient [b] standardized regression coefficient
[c] the PAQ-C represents the overall habitual physical activity score.

Habitual physical activity accounts for very little of the variation in physical fitness, explaining only 5% of the variance in the sit-ups of African boys and the 6% of the variance in the push-ups of Indian boys (Table 73). The PAQ-c does not explain any of the variance in other physical fitness items for African and Indian boys. The PAQ-C also does not contribute significantly to the variance in the physical fitness of European boys and the total sample combined.

The self-reported habitual physical activity levels during specific segments of the day has a slight effect on the physical fitness of the present sample of boys. There is no significant association between physical fitness and reported habitual physical activity of the total sample (Table 74). However, the relationship between reported habitual physical activity and physical fitness is slightly higher for Indian compared to African boys. Habitual physical activity in the evening accounts for 26%, with habitual physical activity during the recess and lunch accounting for an additional 26% and 10%, respectively of the variation in the sit-ups performance of European boys. Habitual physical activity accounts for a total of 52% of the variation in the sit-ups performance

Table 74. Regression analyses of reported habitual physical activity during specific times of the day on selected physical fitness variables by race.

Dependent variable	Independent variable	R^2	B-value[a]	β^b	F
	Physical Activity				
		Total sample			
dash, sec	PE class	0.04	0.18	0.20	12.32**
Grip, kg	Lunch	0.04	-0.63	-0.20	12.84**
	Lunch and	0.06	-0.60	-0.19	9.35**
	Evening		-0.38	-0.13	
Grip, kg/kg	Evenings	0.01	0.01	-0.11	4.09*
Sit and reach, cm	PE class	0.01	-0.55	-0.12	4.15**
		African			
Dash, sec	PE Class	0.06	0.21	-0.24	10.04**
Shuttle run, sec	Lunch	0.04	0.40	0.20	6.65*
Sit and reach, cm	PE Class	0.03	-0.81	-0.17	4.76*
Push-ups, #/30 sec	Lunch	0.04	-1.34	-0.20	6.55*
Nine minute run, m	Lunch	0.03	-51.27	-0.18	5.14*
		Indian			
Dash	Recess	0.04	0.22	0.20	4..66*
Grip, kg	Lunch	0.07	-0.88	-0.26	8.37**
	Lunch and	0.11	-0.81	-0.24	6.71**
	Evening		-0.48	-0.20	6.71**
Shuttle run, sec	PE class	0.11	-0.92	-0.33	14.00**
Standing long jump, cm	Recess	0.10	-5.84	-0.31	12.26**
		European			
Sit-ups, #/30 sec	Evening	0.26	-2.60	-0.51	8.66**
	Evening and	0.42	-3.52	-0.69	8.23**
	Recess		2.18	0.45	
	Evening, and	0.52	-3.77	-0.73	8.26**
	Recess and		2.87	0.59	
	Lunch		-1.59	-0.34	

*p<0.05 **p< 0.01

[a]regression coefficient [b] standardized regression coefficient

of European boys. The performance on some items of physical fitness is thus associated with the estimated level of habitual physical activity at specific times of the day.

Performance on tests of health- and performance-related fitness may be affected by activity, variety in the physical education curriculum, weekly activity time in physical education, involvement in other physical activities, involvement in community organizations (Dotson and Ross, 1985), and present level of physical activity (Dotson and Ross, 1985; Shephard, 1982; Kemper and van Mechelen, 1995). Most schools in South Africa have two 30-minute sessions of physical education per week. However, a large number of schools do not have physical education teachers, and the activity during physical education periods is unstructured and often includes supervised time in class. Furthermore, most Government schools do not have gymnasiums, and this further reduces the opportunities to participate in physical activity in inclement weather.

In the present sample ethnicity appears to play a major role in habitual physical activity and anthropometry. Indian boys are the most sedentary, fattest and have the poorest physical performance on most items compared to African and European boys, whereas European boys are the least sedentary, taller and heavier, and have superior performances on most of the physical fitness tests. While there is no difference in the PAQ-C scores of Africans, Indians and Europeans, Indian boys have the lowest frequency of participation in most of the top ranked physical activities.

The poor physical fitness of Indian boys in the present sample appears to be an artifact of the low levels of physical activity of Indian boys. Indians have the highest sedentary activity, the least light activity, and the lowest estimated total energy expenditure compared to the African and European males. Indian boys engage in less MVPA than African and European boys.

The correlations between estimated energy expenditure and physical fitness, however, are low and explain a minimal percentage of the variance (Table 75). Race-specific regression analyses of estimated energy expenditure in sedentary, light, MVPA and mean daily total estimated energy expenditure were also done (Table 76). Overall, energy expenditure accounts for very little (1% to 2%) of the variation in the physical fitness scores of the total sample.

Estimated energy expenditure accounts for 4% to 6% of the variation in the performance of Indian boys in some physical fitness items. Thus, while Indian boys are more sedentary and have lower estimated energy expenditure in MVPA, estimated energy expenditure explains less of the difference in physical fitness compared to European boys. Indian boys who are more active at higher levels complete more sit-ups and push-ups in 30 seconds compared to more sedentary boys. However, more sedentary boys have better performances on the distance run. Differences in the distance run are not associated with fatness since there is no significant correlation ($r = 0.08$) between estimated energy expenditure in sedentary activity and fatness (sum of five skinfolds). Despite the higher estimated energy expenditure (mean daily total and MVPA) of African boys, estimated energy expenditure differences do not account for variation in physical fitness, except on the dash.

Estimated energy expenditure accounts for minimal variance in physical fitness of African and Indian boys. Modification of behavior patterns during the period of survey

Table 75. Correlations and partial correlations of health-related and performance-related fitness and indicators of activity.

	Estimated energy expenditure (kcal/kg/day)				Partial Correlations: Controlling for Race			
	Sedentary	Light	MVPA	Total	Sedentary	Light	MVPA	Total
Health-related fitness								
Sit-ups	0.07	-0.07	0.12*	0.09	0.07	-0.07	0.12*	0.11
Push-ups	-0.11	-0.01	0.15*	0.09	-0.10	0.00	0.17**	0.13*
9 minute run	0.06	0.03	0.00	0.04	0.06	0.04	0.17	0.06
Sit and reach	-0.11*	0.03	0.13*	0.10	-0.12*	0.00	0.10	0.06
Σ of 6 skinfolds	-0.03	-0.15**	-0.11*	-0.11*	-0.02	-0.14*	-0.10	-0.11
Performance related fitness								
Dash	-0.11	-0.00	0.14**	0.09	-0.11	-0.01	0.13*	0.08
Grip	-0.06	-0.01	-0.07	-0.10	-0.06	-0.01	-0.08	-0.11
Grip, kg/kg	-0.09	-0.02	0.09	0.04	-0.09	-0.02	0.09	0.04
Shuttle run	-0.03	-0.07	-0.07	-0.11*	0.03	-0.06	-0.06	-0.11
Standing long jump	-0.12	-0.02	0.04	-0.01	-0.12*	-0.01	0.05	0.00
PAQ-C	0.04	-0.02	-0.11	-0.10	0.04	-0.02	-0.11	-0.10

Signs for the dash and shuttle run are inverted since a lower score means a better performance.

Table 76. Regression analyses of estimated energy expenditure (kcal/kg/day) on selected physical fitness variables for the total sample, and by race.

Dependent variable	Independent variable	R^2	B-value[a]	β[b]	F
		Total sample			
Dash	MVPA	0.02	-0.03	-0.13	4.88*
Push-ups	MVPA	0.02	0.24	0.16	7.57**
Shuttle run	MTDE[c]	0.01	0.05	0.11	4.05*
Sit and reach	MVPA	0.02	0.15	0.13	5.41*
Sit-ups	MVPA	0.02	0.13	0.13	5.09*
Standing long jump	sedentary	0.01	-1.24	-0.17	4.19*
		European			
Grip	MTDE[c]	0.17	-0.15	-0.42	5.40*
Grip, kg/kg	sedentary	0.17	-0.01	-0.14	5.33*
Pushups	MTDE[c]	0.17	0.52	0.41	5.25*
		Indian			
Nine minute run	sedentary	0.04	34.86	0.20	4.53*
Pushups	MVPA	0.05	0.41	0.22	5.45*
Shuttle run	MTDE[c]	0.05	-18.72	-0.22	5.78*
Sit-ups	MVPA	0.06	0.33	0.25	7.76**
		African			
Dash	sedentary	0.05	-0.13	-0.22	8.34**

*$p<0.05$ **$p<0.01$

Note: signs for dash and shuttle run are inverted.

[a] regression coefficient

[b] standardized regression coefficient

[c] MTDE = mean daily total estimated energy expenditure

and selective recall are other factors that could potentially affect accuracy. Accuracy of the methodology is a possible confounder in this analysis.

Chapter 6

SUMMARY AND CONCLUSIONS

This study considered the interrelationships am ong growth, physical fitness, habitual physical activity, SES, race and nutritional status of 389 ten year old South African boys attending 18 schools in the greater Johannesburg area. Racial classification of subjects was done using anthroscopic appraisal. "Colored" boys were not included in the sample. Boys of African (n = 208) and Indian (n = 137) ancestry were stratified into higher (n = 107, n = 99, respectively) and lower (n = 101, n = 38, respectively) SES groups based on a composite SES score. There were proportionally more lower SES African than Indian boys, and conversely more higher SES Indian than African boys. All boys of European ancestry (n=42) were classified as higher SES. Nutritional status classification of undernourished (BMI-for-age $\leq$ 15th percentile), nutritionally normal (BMI-for-age $>$ 15th but $<$ 85th percentiles), and overweight (BMI-for-age $\geq$ 85th percentiles) was assigned based on the WHO (1995) criterion. Proportionally more Indian boys were classified as undernourished and overweight compared to African boys. Additionally, proportionally more African boys were classified as nutritionally normal compared to Indian boys. A small number of European boys were classified as either undernourished (n=3) or overweight (n=7).

Data for each subject included anthropometry (stature, mass, limb circumferences, skinfold thicknesses, and skeletal breadths), physical fitness (dash, grip, shuttle run, standing long jump, nine minute run, push-ups, sit and reach, and sit-ups), and physical activity (3-day physical activity records [Bouchard et al., 1983] and habitual physical activity patterns [Physical Activity Questionnaire for Children, Kowalski et al., 1997]). Sociodemographic data included demographic statistics, household size, and income, occupation and education of parent/s or guardian/s.

The following research question was addressed: What is the relationship of socioeconomic status, race, and nutritional status to growth status, physical fitness and habitual physical activity of 10-year-old South African boys?.

The growth status of 10 year old South African boys varies with SES, race and nutritional status. Race accounts for a significant but small proportion of the variation in body proportions (sitting height/stature and bicristal/biacromial ratios), subcutaneous fatness (sum of five skinfolds) and relative subcutaneous fat distribution (trunk-extremity skinfold ratio, TER). Race differences remain significant when the effects of SES and nutritional status are controlled as covariates. European boys have proportionally shorter legs relative to stature, and proportionally broader hips relative to the shoulders than African or Indian boys. Further, Indian boys have proportionally broader hips relative to the shoulders compared to African boys. Indian boys are fatter and have proportionally more subcutaneous fat on the trunk compared to the extremities than African and European boys. Additionally, Indian boys have larger estimated arm muscle areas compared to African boys.

Body mass, the sitting height/stature ratio, fatness, relative subcutaneous fat distribution, and estimated arm muscle vary significantly with nutritional status, when race and SES are used as covariates. Nutritional status may be confounded by race since there are proportionally more overweight and undernourished Indian than African or European boys. Overweight boys are obviously heavier than undernourished and nutritionally normal boys, and nutritionally normal boys are heavier than undernourished boys. There are no significant SES, race, and/or nutritional status interactions for body size. Overweight boys have larger accumulations of subcutaneous adipose tissue on the trunk relative to the extremities and larger estimated arm muscle areas than undernourished and nutritionally normal boys, while nutritionally normal boys have more fat and estimated arm muscle than undernourished boys.

Variation in the bicristal/biacromial ratio, body mass and stature with SES are significant when the effects of race and nutritional status are statistically controlled. This trend may also be confounded by race, since all European boys are higher SES. Higher SES boys are taller and heavier, and have proportionally broader hips relative to the shoulders compared to lower SES boys.

Variation associated with SES, race and nutritional status influences several of the health- and performance-related physical fitness tests of 10 year old South African boys. Health-related fitness (sit-ups, push-ups, 9 minute run, sit and reach, and the sum of 5 skinfolds) and performance-related fitness (dash, shuttle run, grip strength, and standing long jump) were considered separately. SES and race do not contribute significantly to the variation in sit-ups, while nutritional status and SES do not contribute significantly to variation in the push-ups, distance run and sit and reach.

There is significant racial variation in health-related fitness (push-ups, distance run, sit and reach, sum of skinfolds) when the effects of SES and nutritional status are controlled. European boys have better fitness on the push-ups and 9 minute run compared to African and Indian boys, who do not differ. However, African boys have greater flexibility of the lower back on the sit and reach compared to Indian boys.

There is no significant SES variation in health-related fitness, but health-related fitness varies significantly with nutritional status. Nutritionally normal boys have better fitness on the sit-ups and sit and reach compared to undernourished boys. Overweight boys are less fit on the sit-ups and 9 minute run compared to undernourished or nutritionally normal boys. Additionally, overweight boys have less muscular strength and endurance of the arms and shoulder girdle as measured by push-ups compared to nutritionally normal boys.

SES, race and nutritional status do not contribute significantly to the variation in two performance-related fitness items, the shuttle run and standing long jump, and SES and race do not contribute significantly to variation in the dash. Race-specific variation in the dash and grip strength per unit mass are significant. Indian boys are the most unfit on the dash and grip strength per unit mass. African and European boys have greater speed in the dash compared to Indian boys, and African boys have greater grip strength per kilogram body mass compared to Indian boys.

Higher SES boys have greater absolute grip strength compared to lower SES boys. This, however, is an artifact of the larger body size of higher SES boys, since the difference in grip strength per unit body mass is not significant.

Overweight boys have poorer performances on the 50 meter dash compared to undernourished and nutritionally normal boys, but have greater absolute grip strength compared to undernourished and nutritionally normal boys. Nutritionally normal boys have better absolute grip strength than undernourished boys. However, the sequence is reversed for grip strength per unit body mass: undernourished are greater than nutritionally normal who are greater than overweight.

SES, race and nutritional status account for a small portion of the variance in the estimated habitual physical activity of 10 year old South African boys. Habitual physical activity was assessed as the time spent on light activity (3 to 5 METS) and MVPA (6 to 9 METS), and mean estimated total daily energy expenditure was also considered. Nutritional status accounts for 41% of the variation in relative estimated energy expenditure (kcal/kg/day) in sedentary activity. SES accounts for an additional 2% of the variation in sedentary activity, while race accounts for 2% of the variation in MVPA (kcal/kg/day).

Racial variation in estimated energy expenditure in sedentary and light activity (kcal/day) is confounded by SES and nutritional status. Racial variation in estimated sedentary and light energy expenditure (kcal/day) is not significant when the effects of SES and nutritional status are controlled. However, Indian boys are significantly less active in MVPA (kcal/day and kcal/kg/day) compared to African and European boys.

SES variation in estimated sedentary energy expenditure (kcal/day) is confounded by body size. The differences between SES groups are not significant when expressed per unit body mass. Similarly, estimated sedentary, light and total energy expenditure (kcal/day) do not differ among nutritional status groups when expressed per unit mass.

There are few differences in the growth status and physical fitness of 10 year old South African boys with different levels of energy expenditure. There are significantly more African boys in the highest quartiles of estimated energy expenditure than Indian boys. Conversely, there are significantly more Indian boys in the lowest quartiles of MVPA and mean daily total estimated energy expenditure. Thus, some of the variation in growth status and physical fitness between boys in the highest and lowest quartiles of estimated energy expenditure probably reflects the racial composition of the quartiles.

The least active African boys are taller and heavier with a higher BMI , and have a higher absolute grip strength than the most active African boys. Additionally, African boys who engage in the most MVPA are shorter and complete more sit-ups in 30 seconds compared to African boys who engage in the least MVPA. This, however, is a function of their larger body since grip strength per unit mass does not differ between boys at the extremes of mean daily total estimated energy expenditure (kcal/kg/day).

Similarly, the least active Indian boys are taller and heavier, and have proportionally longer legs relative to stature compared to the most active boys. There is no difference in the growth and physical fitness of European boys at the extremes of mean daily total estimated energy expenditure, but European boys in the lowest quartile of MVPA are taller than European boys in the highest quartile of MVPA.

Conclusions

Race, SES and nutritional status account for generally small but significant proportions of the variance in measures of the growth status of 10 year old South African boys. The following are the more consistent differences observed in this study:

- Higher SES boys are taller and heavier than lower SES boys when the effects of race are controlled.
- European boys are taller and heavier than African and Indian boys when the effects of SES are controlled.
- Overweight boys are taller and heavier than nutritionally normal or undernourished boys.
- Indian boys have more subcutaneous fat but have a lower BMI than African and European boys.

Race, SES and nutritional status account, in general, for small but significant proportions of the variances in measures of health- and performance-related physical fitness and estimated energy expenditure of 10 year old South African boys. The following trends are suggested by the results of the analyses:

- African boys are more flexible on the sit and reach, while European boys complete more push-ups. Indian boys have the poorest performance on most physical fitness items.
- Undernourished boys have better physical fitness on most test items compared to overweight boys.
- Indian boys engage in the most sedentary activity and have the lowest estimated light and MVPA energy expenditure (kcal/kg/day). Estimated energy expenditure differences between African and European boys are not significant.
- The most physically active African and Indian boys are taller and heavier than the least active African and Indian boys, respectively.

Recommendations.

People of African, Indian and European ancestry in South Africa are not homogenous groups. Thus language and cultural differences that are prevalent within racial groups may have influenced the growth and physical fitness of individuals. The ethnicity (linguistic and cultural groupings) of subjects was not recorded in the present study. The multiethnic nature of South African society must be taken into account for future studies. Additionally, the cultural practices and specifically their significance for physical activity and physical fitness need to be documented.

A more objective method of estimating energy expenditure, such as heart rate recordings or motion sensors, may provide more accurate assessments. These should be complemented by more culturally sensitive observational studies.

There is a paucity of information on the growth, physical fitness, habitual physical activity, and the cultural context of activity and fitness of South Africa Indians. Research should be directed towards building up a database of information on these growth, physical fitness and habitual physical activity, and in particular to study the significance of high subcutaneous fatness in association with a low BMI in individuals of Indian ancestry.

APPENDICES

APPENDIX A

University Committee on Research Involving Human Subjects

MICHIGAN STATE
UNIVERSITY

March 11, 1997

TO: Robert M. Malina
213 IM Sports Circle

RE: IRB#: **97-094**
TITLE: THE EFFECTS OF SOCIOECONOMIC STATUS, ETHNICITY AND NUTRITIONAL STATUS ON THE GROWTH AND PHYSICAL FITNESS OF 10 YEAR OLD SOUTH AFRICAN BOYS
REVISION REQUESTED: N/A
CATEGORY: FULL REVIEW
APPROVAL DATE: 03/10/97

The University Committee on Research Involving Human Subjects'(UCRIHS) review of this project is complete. I am pleased to advise that the rights and welfare of the human subjects appear to be adequately protected and methods to obtain informed consent are appropriate. Therefore, the UCRIHS approved this project and any revisions listed above.

RENEWAL: UCRIHS approval is valid for one calendar year, beginning with the approval date shown above. Investigators planning to continue a project beyond one year must use the green renewal form (enclosed with the original approval letter or when a project is renewed) to seek updated certification. There is a maximum of four such expedited renewals possible. Investigators wishing to continue a project beyond that time need to submit it again for complete review.

REVISIONS: UCRIHS must review any changes in procedures involving human subjects, prior to initiation of the change. If this is done at the time of renewal, please use the green renewal form. To revise an approved protocol at any other time during the year, send your written request to the UCRIHS Chair, requesting revised approval and referencing the project's IRB # and title. Include in your request a description of the change and any revised instruments, consent forms or advertisements that are applicable.

PROBLEMS/ CHANGES: Should either of the following arise during the course of the work, investigators must notify UCRIHS promptly: (1) problems (unexpected side effects, complaints, etc.) involving human subjects or (2) changes in the research environment or new information indicating greater risk to the human subjects than existed when the protocol was previously reviewed and approved.

If we can be of any future help, please do not hesitate to contact us at (517)355-2180 or FAX (517)432-1171.

Sincerely,

David E. Wright, Ph.D.
UCRIHS Chair

DEW:bed

cc: Reshma B. Naidoo

OFFICE OF
RESEARCH AND GRADUATE STUDIES

iiversity Committee on Research Involving Human Subjects (UCRIHS)

Michigan State University
16 Administration Building
East Lansing, Michigan
48824-1046

517/355-2180
FAX: 517/432-1171

APPENDIX B

Consent forms (parents)

The Effects of Socioeconomic Status, Ethnicity, and Nutritional status on the Growth and Physical Fitness of 10 year old South African Boys

CONSENT FORMS (PARENTS)

We are undertaking a study aimed at identifying the environmental factors that affect the growth and physical fitness of children in the Johannesburg area. This study will form the dissertation component of Reshma Naidoo's doctoral program at the Michigan State University, East Lansing, Michigan, USA.

Your son/ward has been chosen as a subject for this study as he is a 10-year-old male attending school in the Johannesburg area. Five hundred 10-year-old boys attending schools in the Johannesburg area will be used as subjects for this study. The participation of your son/ward is voluntary and your son/ward has the right to decide whether to participate or not.

If you agree to allow your son/ward to participate in this study, he will have to complete the following activities. The researcher will interview your son/ward to list the physical activity performed that your son/ward for the past 24 hours. This will be done on three successive days, taking about 10 minutes each day. Additionally, he will have to complete a physical activity questionnaire in which he will record his physical activity patterns for the last week (7 days).

The following tests will be conducted during school time over two days, and will involve a total time of approximately 90 minutes. Some of the boys will be asked to take these tests for a second time, a week later. If your son/ward is selected to take the retest, it will take another 90 minutes (over two days) to complete. His weight, height, breadth of his shoulders and hips will be measured. These measurements will be taken using special instruments. This is completely painless and will not hurt your son/ward in any way. The amount of muscle and fat in the body will be measured using skinfolds and circumference. A skinfold is taken by pinching the skin and measuring the thickness of the skin that is lifted away from the body. This is completely harmless and will cause little pain to your son/ward. Skinfold measurements will be taken at the upper arm, shoulder, stomach, waist, hip and calf.

He will have to perform tests that will determine his physical fitness. These tests will not indicate how good he is at sports. The test results will only be meaningful to the tester when used with the results of all other subjects. He will have to run as far and as fast as he can, continuously, for 9 minutes. He will do as many sit-ups and push-ups as he can for 30 seconds each. He will run 50 meters as fast as he can, and run up and down a 10-meter area around two cones 5 times. His left and right grip strength will be assessed with a handgrip dynamometer (a machine). His sit-and-reach flexibility will be measured.

Although your son/ward will be expected to work very hard, none of these tests are dangerous and every effort will be taken to ensure that no harm comes to him. However, he may be sore and stiff after the physical performance tests if he does not usually exercise this hard. In order to minimize the discomfort, he will be thoroughly warmed-up before and cooled down after the physical performance testing.

Since these tests will cut into the school day, every effort will be made to minimize the loss of academic teaching time, and children will be scheduled at times that are convenient for their teachers and academic schedule. Additionally, a researcher may visit your home and conduct an interview with you. The interview will be used to gain information about your family.

All information and data gathered will be treated with the strictest of confidence and will not be used except for the purposes stated above. The confidence of subjects will be maintained at all times, but may be shared with your, the parent or guardian should your child wish. All participants will remain anonymous in any report of the research findings.

These tests involve no financial costs to you or your family. All materials needed for the testing will be provided. However, on the days of testing, your son/ward will need to be dressed in his physical education outfit that will allow him to perform the tests that will be conducted.

If you have any questions regarding this project, you can contact **Reshma Naidoo** at 67 Somerset Street, Kensington, 2001 (Phone: 011-614-8610), or **Dr. Robert M. Malina** at Institute for the Study of Youth Sports, Michigan State University, East Lansing, Michigan 48825 (Phone: 517-355-7620).

You may keep the above portion of the form and return only the bottom portion.

Please sign and return this form as soon as possible. Thank you very much.

Yours sincerely

____

Reshma Naidoo

The Effects of Socioeconomic Status, Ethnicity, and Nutritional status on the Growth and Physical Fitness of 10 year old South African Boys

CONSENT FORM

I have decided to allow my son/ward ________________________________

to participate in a study of the factors affecting growth and physical fitness of children that will be conducted in his regularly scheduled school day. My signature indicates that I have read the above information, or have had someone read the above information to me, and have given permission for my son/ward to participate in the study. My son's/ward's signature indicates that he understands that a study will be conducted at school and agrees to participate in it. I understand that my son/ward may withdraw at any time (I can choose to discontinue my son/ward's participation in the study) without any negative consequence to me or my family in my present or future relations with Michigan State University.

I understand that if my child is injured as a result of my participation in this research project, Michigan State University will provide emergency medical care if necessary. I further understand that if the injury is not caused by the negligence of MSU I (the parent/ward) am personally responsible for the expense of this emergency care ad any other medical expenses incurred as a result of this injury.

____________________________	__________________
Signature of parent/ guardian	Date
____________________________	__________________
Signature of child	Date
____________________________	__________________
Signature of investigator	Date

Please check here ____ if you would like to keep a copy of this form for your records

Please sign and return this page.

APPENDIX C

Assent form for children

The Effects of Socioeconomic Status, Ethnicity, and Nutritional status on the Growth and Physical Fitness of 10 year old South African Boys

ASSENT FORM FOR CHILDREN

I agree to take part in a study that will address the factors that affect the growth and physical fitness of children. This study has been explained to my mother/father/ guardian and that she/he has given his/her permission for me to participate in this study. I understand that I may decide that I do not want to continue with this study at any time and I can stop at any time I want to. Any information about what I say or do will not be given to anybody else, and will only be used for the purpose of this study.

I understand that I will be asked to complete many physical fitness tests to see how strong and fast I am and that these tests require me to make my best efforts. I also will have to report my physical activity for three days, which includes all the sports and games I play as well as all the running that I do as well as fill in questionnaire about my physical activity over the last 7 days. The tester will take measurement of the length, weight, skinfolds and breadths of my body. I understand that nothing bad or wrong will happen to me if I decide to stop my participation in this study at any time.

When I sign my name to this page, I am indicating that this page was read to me and that I am agreeing to participate in this study. I am indicating that I understand what will be required of me and that I may stop participating in the study at any time.

____________________________ ______________________

Child's signature Date

____________________________ ______________________

Signature of principal investigator Date

APPENDIX D

Sociodemographic information questionnaire (parents)

The Effects of Socioeconomic Status, Ethnicity, and Nutritional status on the Growth and Physical Fitness of 10 year old South African Boys

SOCIODEMOGRAPHIC INFORMATION QUESTIONNAIRE (PARENTS)

1. Subject's name: ______________________________

2. Name: ______________________________

3. Relationship to child: Please check one of the following columns.

Mother	father	aunt	uncle	brother	sister	grandmother	grandfather	other

If you fall into the "other" category, please fill in your relationship to the child

____

4. Home Address: ______________________________
____

5. Which of the following best describes the educational level of the head of the household (male and female)?

Male (father)	Female (Mother)	
		1. Cannot read and write
		2. Can read and write but never went to school
		3. Some elementary (primary) school
		4. Completed elementary (primary) school
		5. Some high(secondary) school
		6. Completed high(secondary) school
		7. Technical college or apprenticeship
		8. College or university degree
		9. Master or doctoral degree

6. I have (fill in the number)

sons		daughters	

7. How many people live in the same house with you? ______________

8. How many rooms are there is your house? __________

9. How many adult live in the same house as you do? ______________

10. How many children live in the same house as you? ______________

11. Some examples of the different occupations given below. Please indicate which of the following best indicates your occupation?
Mother (female head of household): ________________________________
Father (male head of household): ________________________________

College/ University principal	President/ Director/ Chairperson of company	City council or local authority member	Medical doctor	Radio-television and film industry actor
College/ University teacher	Manager	Bank - clerical or lower management	Nurse	Chef
School principal/ Deputy or Vice Principal	Sales	Fireman/ policeperson/ military	Allied health worker	Janitorial/ custodial services
School teacher	Clerical/ Secretarial	Technician	Postal service	Hairdresser/ barber/ beautician
Artist/actor/ Musician	Cashier	Trader/ merchant	Taxi owner	Nanny/ caregiver
Engineer/ architect	Factory worker	Apprentice	Driver/delivery person	Domestic laborer
Lawyer/judge	Cook/baker	Laborer	Farmer	Waiter/waitress/ bartender
Miner	Housekeeper/ Maidservice	Gatekeeper/ Doorman/ Butler	Other	Gardener

12. Please indicate how much you earn each month. Circle the number that reflects your income.

1	less than R417 a month	4	R 1,668 to R3,334 per month
2	R417 to R833 per month	5	R3,335 or R6,667 per month
3	R834 to R1,667 a month	6	R 6,668 per month and more

13. How much does your spouse (or other contributing adult) earn per month? Please circle the number that reflects his/her income.

1	less than R417 a month	4	R 1,668 to R3,334 per month
2	R417 to R833 per month	5	R3,335 or R6,667 per month
3	R834 to R1,667 a month;	6	R 6,668 per month and more

15. How many times has your child been sick in the past year/
____

16. Does your child have intestinal worms (such as round worms or tape worms)?
____

17. Has your child been treated for intestinal worms in the past year?
____

18. Did your child have any intestinal parasites in the past year?
____

Thank you for your assistance in this project.

APPENDIX E

Physical Activity Record

PHYSICAL ACTIVITY RECORD

Name: ______________________________

ID Number: ______________________________

Date and day of activity record: ____________________

This part of the testing process is going to be used to account for your daily activity level. You are going to have to fill in similar forms for three days in a row (Monday, Tuesday, and Wednesday).

For the purposes of recording, each day is divided into before and after breakfast, school, afterschool, before and after supper and before bed. You have to first recall what you did for that segment of time. Write it down and indicate approximately how long you spent on the activity.

When you have performed more than one activity during that time period, use the activity that was most performed during that time. Also indicate if you hyperventilated (breathed heavily) and/or sweated during the activity. Indicate how hard you think that you were working for each of the activities.

If there are any doubts or questions, you can direct them to me (the interviewer) when you are filling in the form.

Thank you very much for helping with this project.

EXAMPLE

For each activity indicate if you sweated, and breathed hard. For each note list a little, not too much, a lot. **Leave the Code column blank**

Time	Activity	Time	Intensity	Code
	got up	6.30 am		
before breakfast.	showered and dressed	6.30 - 7.00	easy	
	breakfast	7 - 7.15 a.m.	light	
after breakfast.	helped to clean up	7.15-7.30 am	sweated	
	walking to school	7.30-7.50	sweat/ breathing hard	
before school	played soccer with friends	7.50-8.05	sweating /breathing hard	
first period	sat - English	8,05 - 8.35		
second	math	8.35-9.05		
third	science	9.05-9.35		
first break	played soccer	9.35-9.50	sweated/breathing hard	
fourth	history	9.50-10.20		
fifth	gymnastics in PE class	10.20-10.50	breathing hard	
sixth period	geography	10.50-11.20		
second break	lunch: played soccer	11.20-11.50	sweated/breathing hard	
seventh period	sat in library class	11.50-12.20		
eight period	stood in music class	12.20-12.50		
ninth period	drew in art class	12.50-1.20		
right living		1.20-1.30		
after school	walked home	1.30-1.45	sweated/ breathing very	
	watched TV	1.45-3.30	hard	
	played ball with friends	3.30 -5.30	sweated/ breathing hard	
before supper	cleaned up the house	5.30 - 6.30	sweated/ breathing hard	
	helped with the laundry			
supper	had dinner	6.30 - 7.00		
after supper	cleared up the kitchen	7.00-7.30	sweated	
	did homework	7.30 - 8.30		
before bedtime	bath	8.30-10.00		
	dressed			
	read			
bedtime	slept	10.00		

Name: ______________________ ID #____________________ Day:

Monday

For each activity indicate if you sweated, and breathed hard. For each note list a little, not too much, a lot. **Leave the Code column blank**

	Activity	Amount of time	Effort	Code
	got up at			
Before breakfast				
Breakfast				
After breakfast				
Before lunch				
During lunch				
After lunch				
Before supper				
During supper				
After supper				
Before bedtime				
Bedtime				

Name: ____________________ ID #__________ Day: Tue/Wed

For each activity indicate if you sweated, and breathed hard. For each note list a little, not too much, a lot. **Leave the Code column blank**

	Activity	**Amount of time**	**Effort**	**Code**
	Got up at			
Before breakfast				
Breakfast				
After breakfast				
Before school				
First period				
Second period				
Third period				
First break				
Fourth period				
Fifth period				
Sixth period				
Second break				
Seventh period				
Eight period				
Ninth period				
After school				
Before supper				
During supper				
After supper				
	Bed			

Leave this section blank. It is for use by the investigator.

Summary:

1	2	3	4	5	6	7	8	9

APPENDIX F

Habitual Physical Activity Questionnaire

The Effects of Socioeconomic Status, Ethnicity, and Nutritional status on the Growth and Physical Fitness of 10 year old South African Boys

HABITUAL PHYSICAL ACTIVITY QUESTIONNAIRE

Name: ____ ID #:_________

School:____

We are trying to find out about your physical activity levels that you have done in the last 7 days (in the last week). This includes sports or dance that make you sweat or make your legs feel tired, or games tat make you breathe harder, like tag, skipping, running, climbing and others.

Remember: There are no right or wrong answers -- this is not a test.

Please answer all the question as honestly and accurately as you can -- this is very important.

1. In the last 7 days, during your physical education (PE) classes, how often were you very active (playing hard, running, jumping, throwing)?

I don't do PE	
Hardly ever	
Sometimes	
Quite often	
Always	

2. In the last 7 days, what did you do most of the time AT RECESS?

Sat down (Talking, reading, doing school work)	
Stood around or walked around	
Ran or played a little bit	
Ran and played hard most of the time	

3. In the last 7 days, what did you do normally do AT LUNCH (besides eating lunch)?

Sat down (Talking, reading, doing school work)	
Stood around or walked around	
Ran or played a little bit	
Ran and played hard most of the time	

4. In the last 7 days, on how many days RIGHT AFTER SCHOOL, did you do sports, dance, play games, or hard work in which you were very active?

None	
1 time last week	
2 or 3 times last week	
4 times last week	
5 times last week	

5. In the last 7 days, on how many days EVENINGS, did you do sports, dance, play games, or do hard work in which you were very active?

None	
1 time last week	
2 or 3 times last week	
4 or 5 times last week	
6 or 7 times last week	

6. ON THE LAST WEEKEND, how many times did you do sports, dance, play games, or do hard work in which you were very active

None	
1 time last week	
2 or 3 times last week	
4 or 5 times last week	
6 or 7 times last week	

7. Which ONE of the following describes you best for the last 7 days?

A	All or most of in the time that I was not at school was spent doing things that involve little physical effort (e.g. watching TV, doing homework, playing computer games)	
B	I sometimes (1 - 2 times last week) did physical things in the time that I was not at school (e.g. played sports, went running, swimming, gardening, washed the car)	
C	I often (3 - 4 times last week) did physical things in the time that I was not at school	
D.	I quite often (5 -6 times last week) did physical things in the time that I was not at school	
E	I often (7 or more times last week) did physical things in the time that I was not at school	

8. How fit (in good shape) do you think you are compared to other boys of your age?

Very fit	
Fitter than most	
About average	
Less fit than most	
Very unfit	

9. Were you sick last week, or did anything prevent you from doing your normal physical activities?

Yes	
No	

If yes, what prevented you?______________________________

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