TRACKING PHYSICAL GROWTH AND HEALTH STATUS OF SOUTH AFRICAN RURAL CHILDREN: ELLISRAS LONGITUDINAL STUDY (ELS)

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The author
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AFRIKAANSE TITEL

'n Ondersoek na die groei en gesondheidstatus van Suid-Afrikaanse plattelandse kinders: Ellisrasse Longitudinale Studie (ELS)

OPSOMMING

Motivering

In onderontwikkelde en ontwikkelende lande is wanvoeding 'n belangrike oorsaak van sterftes. Ten spyte van die gevestigde gebruik van antropometrie om die groei en voedingstatus van kinders in Afrika deur middel van dwarsdeursnitstudies te bepaal, bly sekere vraagstukke onopgelos. Die toenemend eskalerende koste van mediese en gesondheidsdienste moet bekamp word. Die gemeenskap sal veel beter gedien word deur navorsingmetodes toe te spits op voorkomende maatreëls. Omdat die voedingstatus van Suid-Afrikaanse plattelandse kinders as 'n al hoe groter wordende sosiale probleem beskou moet word, is longitudinale studies nodig om hierdie probleem aan te spreek.

Doelwitte

In hierdie proefskrif sal kroniese en akute wanvoeding op sowel 'n dwarsdeursnit as 'n longitudinale wyse by Suid-Afrikaanse plattelandse kinders tussen ouderdomme 3 en 12 jaar wat aan die Ellisrasse longitudinale studie deelneem, ondersoek word. Data is versamel vanaf November 1996 tot November 1998. Die doel van die navorsing is viervoudig:

- Om die groei- en voedingstatus van Ellisrasse plattelandse kinders tussen 3 en 10 jaar oud te beskryf.
- Om die voorkoms van belemmerde groei en uittering by 'n verteenwoordigende versameling Ellisrasse plattelandse kinders tussen 3 en 10 jaar in verhouding tot hulle sosio-ekonomiese agtergrond, te bepaal.
- Om die voedingstoestande van Ellisrasse plattelandse kinders tussen 3 en 12 jaar oud te ondersoek deur die stabiliteit van antropometriese aanwysers oor 'n tydperk van twee jaar (1996-1998) te evalueer.
- Om die stabiliteit van somatotipes in Ellisrasse kinders tussen 3 en 12 jaar in verhouding tot hulle gesondheidstatus na te vors.

Metodiek

Antropometriese metings wat liggaamslengte, liggaamsmassa, omtrekmates (kuit, gespanne boarm) deursneemates (bi-epikondilêre humerus en femur) en velvoue (triseps, subskapulêr, supraspinaal en kuit) insluit, is geneem vanaf November 1996 tot November 1998 van kinders wat deelgeneem het aan die Ellisrasse longitudinale studie volgens standaardprosedures wat deur Norton & Olds (1996) aanbeveel word. Die totale aantal proefpersone betrokke by hierdie navorsing word duidelik gemeld in elke gepubliseerde teks van hierdie studie. Om die voorkoms van wanvoeding in die groep proefpersone te ondersoek, is gebruik gemaak van die National Health and Nutritional Examination Survey (NHANES III) of die National Centre for Health Statistics (NCHS) se verwysingsdata om die verhouding liggaamsmassa-tot-ouderdom en lengte-tot-ouderdom en liggaamsmassa-tot-lengte Z-telling te bepaal. Die broodwinner se beroep was die uitgangspunt waarvolgens die sosio-ekonomiese status van elke proefpersoon in verhouding tot sy of haar voedingstatus beskryf is. Die Heath-Carter somatotiperingsmetode is gebruik om hierdie kinders te somatotipeer.

Resultate en bespreking van die ondersoek

- Met die ontleding van die resultate van die dwarsdeursnitkomponent, is dit duidelik dat die ELS-kinders vir reg deur die groep swak groei ervaar. Lengtegroeipatrone dui daarop dat hierdie kinders tot op die ouderdom van 6 jaar ewewydig aan die 50ste persentiel van die NHANES III groei. Daarna vertoon albei geslagte 'n geleidelike afname in die snelheid van lengtegroei tot 'n geraamde 0.5 cm per jaar afwyking van die normale lengte. Onder albei geslagte is die toename in gewig konstant tussen 1 en 2 kg per jaar in teenstelling met dié van die kontrolegroep wat geleidelik tot ongeveer 3 kg per jaar tot op die ouderdom van 10 jaar toegeneem het. Die voorkoms van kroniese en akute wanvoeding was vir hierdie groep proefpersone hoog met 'n toename in ouderdom.

- Die voorkoms van belemmerde groei by al drie die sosio-ekonomiese groepe (hoog, gemiddeld en laag) wissel van 19.9% tot 51.0% terwyl uittering van 22.8% tot 39.9% wissel in al die sosio-ekonomiese groepe. Daar vind 'n voortdurende, maar opvallend selektiewe, sosiale uitdunning tussen hoër en laer sosiale stande in die Ellisrasse Plattelandse gemeenskap plaas.

- Kinders van Ellisras ervaar oor die algemeen swak voedingstoestande. Navorsing het aangetoon dat swak voedingstoestande oor die tydperk van twee jaar relatief konstant gebly het. Dit blyk verder dat die akute en kroniese swak voedingstoestande van die ELS-kinders betrokke in hierdie studie nie verbeter nie, maar eerder verswak met die toename in ouderdom. Die sterk positiewe kontinuïteitskoëffisiënt in hierdie groep proefpersone verhoog die voorspelbaarheid van toekomstige waardes van die kind wat akute en kroniese wanvoedingstoestande aan die begin van die studie ervaar het.

- Ellisrasse plattelandse seuns bly stabiel terwyl ander seuns twee tot ses keer meer veranderlik as normale kinders is. Hulle gemiddelde somatotipes varieer van gebalanseerde ektomorfie tot mesomorfiese ektomorfie en omgekeerd oor die tydperk. Migreerafstande toon aan dat die somatotipe van party seuns stabiel is terwyl dié van ander wissel met verandering tot en met 2 of meer maal groter as die somatotipe van die stabielste seuns. Die tussen-ouderdomse gedeeltelike korrelasie vir endo- en ektomorfie is hoog en beduidend maar laag en onbeduidend ten opsigte van mesomorfie.

- Party meisies in elke groep is stabiel, terwyl ander uiters veranderlik is met noemenswaardige groter veranderinge as by die stabielste meisies. Die gemiddelde somatotipe van mesomorf-ektomorf wissel tot gebalanseerde ektomorf onder voorskoolse meisies, asook van mesomorfiese ektomorf en mesomorf-ektomorf tot gebalanseerde ektomorf onder die laerskoolmeisies. Evaluering van die migreerafstandspatrone oor 'n tydperk van twee jaar dui aan dat somatotipes van indiwidue beduidende veranderinge mag vertoon. Migreringsafstandwaardes wissel tussen 2.6 en 24.4. Dit dui daarop dat sommige voorskoolse meisies tot 6.9 keer en laerskoolmeisies tot 7.2 keer veranderliker as die ander is. Die ontleding van somatotipe bevestig die swak voedingstatus van hierdie meisies.

Samevattende bespreking

Die voorkoms van akute en kroniese wanvoeding is hoog onder Suid-Afrikaanse plattelandse kinders ongeag hulle sosio-ekonomiese status. Dit verklaar moontlik die fluktuering van die somatotipekomponente wat in hierdie studie na vore kom. Gesonde, aktiewe en goed gevoede kinders is 'n fundamentele voorvereiste vir volgehoue ekonomiese ontwikkeling. Dit is nogtans belangrik om in gedagte te hou dat die hoë waardes van die aanwysers vir uittering en belemmerde groei in hierdie studie van groot belang vir die Suid-Afrikaanse plattelandse bevolking is. Ingrypings om die voedingstatus van plattelandse Suid-Afrikaanse kinders te bevorder, moet dus alreeds op jong kinders toegespits word.

Sleutelwoorde: Groei, groeisnelheid, voedingstatus, antropometrie, geslagtelike verskille, stabiliteit, somatotipe, sosio-ekonomiese status, Suid-Afrikaanse plattelandse kinders.

SUMMARY

Motivation

In under-developed and developing countries malnutrition is a major cause of mortality. Despite the long-standing use of anthropometry for assessing growth and nutritional status of children in Africa based on cross-sectional studies, a number of issues remained unresolved. Today there is an increasing awareness that the spiraling cost of medical and health services must be stopped and that our society would be better served by devoting more effort to research in methods of primary prevention. Hence longitudinal studies are needed to combat the nutritional status of rural South African children, which is clearly seen as a growing social problem.

Objectives

In this thesis chronic and acute malnutrition will be investigated both cross-sectionally and longitudinally in rural South African children aged 3 to 12 years who will participate in the Ellisras Longitudinal Study (ELS). Data was collected from November 1996 to November 1998. The aim of the study is fourfold:

- to describe the growth and nutritional status of Ellisras rural children aged 3-10 years old
- to determine the prevalence of stunting and wasting in a cross-sectional sample of Ellisras rural children aged 3 to 10 years in relation to their socio-economic background
- to assess tracking of the nutritional conditions of Ellisras rural children aged 3 to 12 years by means of evaluating the stability of anthropometric indicators over a two-year period (1996-1998) and
- to investigate the stability of somatotype in Ellisras children aged 3 to 12 and relate this to their nutritional status.

Methodology

Anthropometric measurements which include height, weight, body circumferences (calf, upper arm flexed), breadths (bi-epicondylar humerus and femur) and skinfolds (triceps, subscapular, supraspinale, calf) were carried out from November 1996 to November 1998 on children who participated in the Ellisras Longitudinal Study according to standard procedures recommended by Norton & Olds (1996). The total number of subjects in the study is clearly stated in each published paper of this thesis. To examine the prevalence of malnutrition in the sample, the National Health and Nutritional Examination Survey (NHANES III) or National Centre for Health Statistics (NCHS) reference data were used to determine both the weight-for-age and height-for-age and weight-for-height Z score. The breadwinner's occupation was used to describe the socio-economic status of each subject in relation to his or her nutritional status. The Heath-Carter method of somatotyping was used to somatotype these children.

Results and Discussion of the individual studies:

- In analysing the results cross-sectionally, it is evident that the ELS children experience poor growth throughout the age group. Patterns of growth in height suggest that these children grow parallel to the 50^{th} centile of the NHANES III up to age six and then both sexes demonstrate a gradual decline in height velocity such that their mean heights diverge by approximately 0.5 cm per year. In both sexes increase in weight is consistently between 1 and 2kg per year in contrast to the increments of the reference sample that gradually increase to approximately 3kg per year by 10 years of age. The prevalence of chronic and acute malnutrition was high for this sample at an older age.

- The prevalence of stunting in all three (high, moderate and low) socio-economic groups ranged from 19.9% to 51.0%, while for wasting it ranged from 22.8% to 39.9% in all socio-economic groups. There is an ongoing social dilution of higher and lower social classes in the Ellisras rural community, but with considerable selectivity in the process.

- Ellisras children generally experience poor nutritional conditions. Based on the tracking analyses, it is clear that poor nutritional status is relatively stable over a period of two years. It appears that the acute and chronic poor nutritional conditions of the ELS children in this report do not improve but instead worsen with increasing age. The strong positive tracking coefficients in this sample could enhance the prediction of future values for the subject who experiences acute and chronic poor nutritional conditions at the initial stage of the measurements.

- Ellisras rural boys are stable while others are extremely variable with changes of two to six times greater than the most stable boys are. Their mean somatotypes shift from balanced ectomorphy to mesomorphic ectomorph and vice versa over time. Migratory distances (MD) showed that the somatotype of some boys are stable while those of others vary with changes up to two or more times greater than the most stable boys. The inter-age partial correlations for endomorphs and ectomorphy are high and significant but low and insignificant in mesomorphy.

- Some girls in each group are stable while others are extremely variable with substantially greater changes than the most stable girls. The mean somatotype shifts from mesomorph-ectomorph to balanced ectomorph for the pre-school girls as well as from mesomorphic ectomorph and mesomorph-ectomorph to balanced ectomorph in the primary school girls. Examination of MD patterns over two years indicates that the somatotypes of individuals may show considerable change. MD values ranged from 2.6 to 24.4. This indicates that some pre-school girls vary up to 6.9 times and primary school girls 7.2 times more than others. Somatotype analysis confirms the poor nutritional status of these girls.

Combined discussion

The prevalence of acute and chronic malnutrition is high in rural South African children, irrespective of their socio-economic status. This probably accounts for the fluctuations in the somatotype components found in the present study. Healthy, active and well-nourished children are a fundamental pre-requisite for sustained economic development.

Nevertheless, it seems important to take into account the fact that the high values for the indicators of wasting and stunting in this study are of major concern to the South African rural population. Therefore, interventions to improve the nutritional status of rural South African children should already be focussed on young children.

Key words: Growth, velocity growth, nutritional status, anthropometry, sex differences, stability, somatotype, socio-economic status, rural South Africa children.

Ellisras Rural Area

Pashasha House for research team members

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LIST OF ABBREVIATIONS

ELS	Ellisras Longitudinal Study
NP	Northern Province
WHO	World Health Organization
WAZ	Weight-for-age
HAZ	Height-for-age
WHZ	Weight-for-height
BMI	Body mass index
US	United States
NCHS	National Center for Health Statistics
CDC	Center for Disease Control
NHANES	United State Health and Nutritional Examination Survey
CSD	Center for Science and Development
HSRC	Human Science Research Council
MRC	Medical Research Council
ISAK	International Society for the Advancement of Kinanthropometry
TEM	Technical error of measurement
MD	Migratory Distance
SAD	Somatotype attitudinal distance
SAM	Somatotype attitudinal means
Ht	Height
Wt	Weight
M	Mean
SD	Standard Deviation
%	Percentage
SES	Socioeconomic status
BC	Before Christ
F	Fat
M	Muscularity
L	Linearity

ELS Research team members from 1996 - 2000

1

BACKGROUND, MOTIVATION AND AIMS OF THE STUDY

1.1 Introduction

To date, the cost of medicine is increasing daily (Kemper, 1985). In Africa, medical science is in daily contact with the fearful consequences of under-nutrition, manifested in conditions such as protein-energy malnutrition and micro nutrients deficiencies (Smit, 1968; Cameron, 1992; Steyn & Walker, 2000). Nutritional status is a term commonly used to refer to the physical condition of an individual or a group as apparently influenced by their food intake (Smit, 1968; Cameron, 1992). Undernutrition, nutrient or dietary imbalance and excessive food intake constitute what is commonly called malnutrition. The emphasis of nutritional science falls on prevention, to which end a knowledge of nutritional status becomes essential (Smit, 1968; Gorstein & Akre, 1988).

According to the World Health Organisation (1983; 1986), the growth status (i.e. attained size, level of maturation or performance at a given point in time) of children is the best indicator of the overall health and nutritional status in a community, especially in the developing areas of the world. Measurements and observation of the child or a group of children taken at several points in time provide indications of growth progress over time. Malnutrition and undernutrition and more specifically low protein intake were reported to be possible contributory causes of the growth retardation in African children (Cameron, 1991).

The physical growth process can be interrupted by malnutrition at any time between infancy and adolescence. The extent of growth retardation that takes place depends on the severity, duration and time of onset of malnutrition (Cameron, 1991). Malnutrition may also serve as a mediating condition for certain diseases that affect physical growth. According to Gallahue and Ozmun (1989:216), children that suffer from acute and chronic malnutrition, particularly during infancy and early childhood, never completely catch up to the growth norms for their age levels, and, as a result, suffer from growth retardation. Growth retardation is found among different ethnic groups and income levels of families. Children of low-income families generally have poor diets simply because they live on food of low nutrient density (Steyn et al., 1998; Cameron et al., 1998; Steyn & Walker, 2000). Preece (1989) reported that the feeding style of low income families is the main reason for malnutrition because the quantity of food available to all members is less due to unequal distribution and low income parents tend to be more permissive about the eating habits of their children. Physique of these children becomes leaner through to adolescence. Prolonged dietary deficiency and excesses can have a serious impact on the growth pattern of the children (Gallahue & Ozmun, 1989:216).

Many children in the developing world live under marginal and inadequate nutritional conditions, primarily with deficiency in protein, energy intake and also vitamin A and iron deficiency (Eveleth & Tanner, 1991; Steyn, 1999; Steyn & Walker, 2000). The net result is chronic protein energy undernutrition which is often called protein energy malnutrition (Cameron, 1991). Between the period 1963 –1973 the prevalence of chronic protein energy malnutrition was 31% in Africa, 51% in Asia and 22% in Oceanic and Latin America was 26%. From the period 1973 to 1983 the prevalence of malnutrition in Africa declined to 21.9%, 8.6% in Latin America and increased to 114.6 % in Asia (WHO, 1983). A recent report indicates that in Africa 38.6% of pre-school children are stunted and 27.4% are underweight for age (De Onis et al., 1993), thus 44.6 million children are stunted and 31.6 million are underweight (Visschedijk & Simeant, 1998). The highest prevalence of stunting and underweight are found in East Africa, 47.0% and 31.0%, respectively and in west Africa, 37.9 and 32.8% respectively (Steyn & Walker, 2000). The prevalence of stunting and wasting are lower in Northern Africa, where they are 25.4 and 11.3%, respectively. While there are limited data in Southern Africa, statistics indicate that the prevalence of stunting lies between 22.9 and 30.3% and underweight between 9.3% and 26.2% (Steyn & Walker, 2000). Labadarios and Van Middelkoop (1995) have reported the lowest percentage of stunting and underweight (29.9% and 9.3%, respectively) in South African pre-school children. It is important to note that even in the new millennium protein energy malnutrition is still a major concern in the developing world. However, the stability of malnutrition in all the studies of protein energy malnutrition was hardly investigated.

1.2 Problem statement

Poor physical growth and somatotype that is most dominant in the ectomorphy continuum of undernourished children have been reported in the whole world (Carter and Heath, 1990). The growth curves of children from areas with chronic mild to moderate protein energy malnutrition begins to move away from that of well-nourished children (Ramos, 1975; Richardson, 1978; Martorell et al., 1992). After 6 months of age, mean values for height and weight continued to move towards the lower percentile value and stabilized at the 5th and 10th percentiles in the 2nd

and 3rd years of life (Scholl, 1975; Cameron, 1991). For children of lower socioeconomic status of South Mexico, growth of stunted children occurred during early childhood and persisted through middle childhood and adolescence (Ramos, 1975; Frisancho, 1981). The chronically undernourished school children remain small on the average and their adolescent growth spurt is delayed. Their somatotype is more clustered in the ectomorphy continuum (Carter & Heath, 1990).

An undernourished child is more susceptible to infectious or parasitic disease (Frisancho, 1981). For example, many parasites that are located in the intestinal tract are responsible for diarrhoea and dysentery, which contribute to the deterioration of the nutritional status of chronically, undernourished children. The role of climatic conditions, habits of personal hygiene and lack of adequate sanitation facilities, especially drinking water and waist disposal, are particularly important factors in the maintenance and spread of infectious and parasitic diseases in many areas of the world (Malina & Bouchard, 1991). Intestinal parasitic infestation is a significant factor affecting the growth of preschool children in the developing areas of the world (Malina & Bouchard, 1991). For example, among 102 pre-school children in a rural Guatemalan community, about 54% had ascaris, 27% had guadia and 8% had amoebae, and many had multiple intestinal parasites (Martorell et al., 1975). Over a period of one-year children who were treated for parasitic load gained 0.28kg of weight and 0.95cm more in stature. The gaining of weight and length of mild-to-moderate protein energy malnutrition children in Guatemala at 7 years of age was less than that of the well-nourished children by an average of 4.9kg and 12.8cm respectively (Martorell et al., 1975).

Furthermore, infections and parasitic disease, cultural practice and lack of education contribute to the poor growth of chronically mild-to-moderate undernourished children (Martorell et al., 1975; Cameron et al., 1992). Illiterate and cultural practices play an important role in affecting the nutritional status of pre-school children (Malina & Bouchard, 1991). For example, food distribution within the families follows local cultural patterns and more often children are fed last. There is a belief that children with chronic diarrhoea should not be fed. It is also believed that solid food would further upset the stomach of a child with fever or diarrhoea (Malina & Bouchard, 1991). A loss of appetite accompanies high fever and severs diarrhoea and when the child does not request food (having no appetite) many mothers do not provide it. The net result is less energy available to the child who is already undernourished at the time when she/he needs it (Martorell et al., 1992). However, the stability of these poor nutritional conditions in children, together with the stability of their somatotype, has not been adequately investigated. Hence a comprehensive investigation of nutritional inadequacy and somatotype of rural children of South Africa will help the South African government to improve the growth and health status of its rural population.

1.3 Aims

In this research, nutritional status of rural South African children will be investigated longitudinally in the Ellisras rural area for a period of two years. Therefore, this research project is called the Ellisras Longitudinal Study (ELS).

The aims of the study are as follows:

- to describe the growth and nutritional status of Ellisras rural children aged 3-10 years old,
- to determine the prevalence of stunting and wasting in a cross-sectional sample of Ellisras rural children aged 3 to 10 years in relation to their socioeconomic background,
- to asses tracking of the nutritional conditions of Ellisras rural children aged 3 to 12 years by evaluating the stability of anthropometric indicators over a two-year period (1996-1998) and
- To investigate the stability of somatotype in Ellisras children aged 3 to 12 and to relate this to their nutritional status.

1.4 Structure of the thesis

Data used in this thesis are from ELS (Monyeki et al., 2000). This thesis consists of three published papers and two manuscripts submitted for publication.

- Chapter two- gives an overview of physical growth and health status of rural South African children (literature review).
- Chapter three describes the physical and nutritional conditions of rural South African children.
- Chapter four focuses on the relationship between poor nutritional conditions and the socioeconomic conditions.
- Chapters five to seven look at the stability of malnutrition and somatotype in this population.

- Chapter eight comprises the summary, conclusions and recommendations.

This thesis does not contain a single reference list, but the relevant references are provided at the end of each chapter according to the author's instructions of the specific journal in which the papers were published or submitted for publications. The relevant references used in the unpublished chapter 1, 2 and 8 are provided according to the mandatory style, stipulated by the Potchefstroom University for CHE. The technical style used in the unpublished chapter is uniform, but differs in the other chapters according to the authors instructions of the specific journals.

1.5 Scope and significance of the study

Whilst most studies have been documented on infants and adolescents, the period between infancy and adolescence has received less attention although it represents an important psycho-social and perhaps physical transitional period in the life of the child. Pre-school children (age 3 to 5 years) have their normal school period being 9:00 to 13:00 hours from Monday to Friday and mostly at a stone's throw distance from their home. In South Africa, formal daily schooling for children is between 7:30 to 16:30 hours. However, because of the distance they have to travel between the home and the school many of these primary school children leave home about 6:00 hours and return late in the afternoon (about 18:00 hours). For the majority of the children who start in the primary school, this period marks the end of total dependence on the mother and first interaction with a wider community through formal schooling. In situations in which meals are not provided at school, this may also represent a time of nutritional transition to a more varied and perhaps less stable diet.

The desire of the South African government to improve the health of rural people requires that adequate baseline data is available to evaluate the effects of improved growth and health care. This will help in reducing the influx of rural people to urban communities as Van der Merwe (1988) earlier reported.

The current ELS was designed to investigate the growth and health status of rural children attending formal pre-school and primary school in rural area of South Africa. Such children aged

3 to 10 years thus form a legitimate target population to add detailed information to bridge the gap of knowledge in previous information on infants and adolescents.

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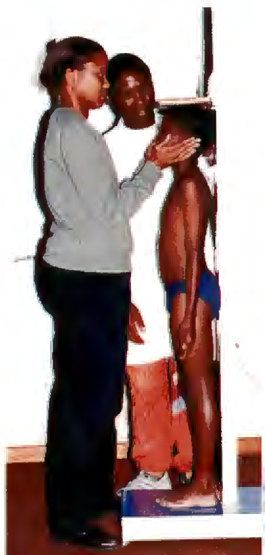
Anthropometric & Blood Pressure survey in ELS



2

LITERATURE REVIEW

2.1 Introduction

The Northern Province (NP) has a population of 4.1 million of which 75.3% are black South Africans and 88% live in rural areas. The NP has the lowest literacy rate (53%) of all the provinces in South Africa and the highest unemployment rate (41%) (Central Statistics Service, 1996; 1997). There is an increasing awareness that the spiraling cost of medical and health service must be stopped and that our society would be better served by devoting more efforts to researching methods of primary prevention (Kemper, 1985). This change in attitude has increased the demand for further knowledge about malnutrition, the influence of the environment on health and about the effect of changes in life style. One very important line of research in prevention is concerned with the early detection of the population at risk and further development of intervention techniques to reduce the probability of morbidity of these populations. The longitudinal approach is most suitable for the elaboration of methods of early detection, particularly in the NP, where many people are reported to be illiterate (Central Statistics Service, 1996; 1997).

Physical growth in South African children has been the subject of several studies during the past 50 years and these were mostly cross-sectional (Le Riche, 1940; Grobbelaar, 1967; Smit, 1968; Walker & Walker, 1977; Richardson, 1978; Cameron et al., 1988; 1992; 1998; Cameron, 1991; Steyn et al., 1992; Monyeki et al., 1995). Because of the need to evaluate nutritional status in order to guide intervention programmes, many of the earlier studies focused on the growth and the development of children during the first five years of life. Later, interest in adolescence and pubertal development led to further studies aimed specifically at older children. These studies revealed that growth rates of height and weight of children are considered to be the best dynamic indicators of nutritional and health status. Furthermore, a high prevalence of stunting in infancy and delayed adolescence were reported. Little longitudinal data of growth on the same group of children during childhood, adolescence and adulthood have been reported from undernourished populations of South Africa. Height increments and height deficits effectively reflect a long-term picture of nutritional adequacy (Seoane & Latham, 1971) if studied longitudinally.

In a longitudinal study, individual changes in growth and development of an individual can only be studied if he/she has been measured repeatedly over time. The basic definition of a longitudinal study requires the same assessment of the subject at a minimum of two points of time in their lives (Kemper, 1985). The two points should be widely spaced over several years rather than a few months or weeks. Mednick and Baert (1981) distinguish between two types of longitudinal research, namely the correlative or non-interventive longitudinal research and the manipulative or experimental type of longitudinal research. In the non-interventive type of longitudinal research, early characteristics are noted and correlated with outcomes at later stages of development (Kemper, 1985; Twisk et al., 1996). Most of the prospective longitudinal research is correlative. However, in such research there can be no attempts to establish causal relationships. If a longitudinal research takes on an interventative nature, it becomes experimental-manipulative. Assuming that proper control and research design are used, certain types of causal statements can be made concerning the conclusions of such research. Longitudinal studies are very seldom found in the literature. Kemper (1985) identifies the following reasons why such studies have been very few:

- Long-term financial commitment: because of the high cost, a guarantee of continuous financial support is needed.
- Techniques become obsolete: measures and techniques that seem important at the start may be out of date several years later.
- Long term commitment of staff and subjects: it is difficult to achieve the final stage of analysis and publication of the results.
- The confounding effects that inevitably occur in repeated measurements.

Despite all the problems related to studying a population longitudinally as pointed out by Kemper (1985), it is important for rural populations of South Africa to be studied.

It is well known that children belonging to poor socio-economic groups, particularly those from rural areas of developing countries, have short stature as adults (Kamala et al., 1972). It is also a known fact that children from developing countries experience poor nutritional conditions up to the age of 3 or 4 years and are predominantly ectomorphic (Malina & Bouchard, 1991; De Ridder, 1993; Monyeki et al., 1995; Monyeki et al., 1999b). The effect of protein-energy malnutrition on growth depends on the timing (when it occurs), severity (how serious it is) and duration (how long it persists) of the nutritional stress (Malina & Bouchard, 1991). An investigation into these aspects will help to explain growth in rural areas in the South African context.

2.2 Tracking growth and health indicators in children

Because of the need to improve the growth and health status of any given population, longitudinal studies are vital since they assist in tracking malnutrition, physique, influence of environment on health and the effect of changes in life style. Tracking can be defined as the stability of certain measurements over time or the predictability of measurements to certain risk factors later in life (Twisk et al., 1997; Van Lenthe et al., 1996). Because tracking relates to the predictability of values later in life from early measurements, a tracking analysis can also be used for early detection of risk factors of chronic diseases. If tracking exists for a certain risk factor, the subject at risk can be identified at an early age and, therefore, preventative strategies can start as soon as possible from that age on. Tracking is mostly used in relation to risk factors of chronic diseases (Van Lenthe et al., 1996; Twisk et al., 1994). Early detection of these risk factors can lead to the possibility of early treatment. It is consequently important to determine the stability of a certain risk factor over time.

Twisk et al. (1994:181-182) summarised the following for choosing a tracking coefficient in their paper, "Mathematical and analytical aspects of tracking":

- " One should take as many time points as feasible, as spread out over the time period as much as possible.
- One should use a measurement that is as sensitive and reliable as possible with uncorrelated errors.
- The coefficient has to be interpreted easily. A coefficient which values can range between 0.0 for no tracking and 1.0 for perfect tracking seems to be the most appropriate. A coefficient that does not equal zero when applied to random numbers or is not 1 by perfect tracking should be re-scaled.

- In most studies, only a point estimate of a tracking coefficient is given. Conclusions based on a point estimate are questionable because no information about reliability is taken into account. They suggested the need to calculate a 95 percent confidence interval around the tracking coefficient, so that a conclusion can be made more thoroughly.
- It is very dangerous to provide strict rules for the interpretation of a tracking coefficient because the values of a coefficient are very dependent on the period under consideration. Probably the best strategy is to give some advice about the interpretation of the values of the coefficient and let the reader decide what to do with the results".

According to Cameron (1991) generally, conclusions about the tracking phenomenon are based on the significance of a tracking coefficient for the subjects at risk of either chronic or acute poor nutritional conditions. The magnitude of the tracking coefficients gives the most important information about the tracking phenomenon (Twisk et al., 1994). However, tracking coefficients greatly depend on the initial measurements and the length of the period (Van Lenthe et al., 1996; Twisk et al., 1997). Studies assessing tracking in height have been performed from adolescence to adulthood in Australia (Brown & Townsend, 1982), Belgium (Hauspie & Wachholder, 1986) and Guatemala (Bogin et al., 1990). A strong positive correlation (r around 0.80) was found for height in all these studies. However, studies evaluating anthropometric indicators of wasting and stunting in African populations are hardly available.

Despite the long-standing use of anthropometry for assessing growth and nutritional status of children in Africa based on cross-sectional studies, a number of issues remain unresolved. With the steady decline in food production in Africa (Jennings & Strret, 1989; Steyn et al., 1998), the stability of malnutrition from anthropometric indices in the life span of an African child, has not been addressed. Ellisras rural children were reported to be stunted and wasted even at an older age (Monyeki et al., 2000), with the absence of the prevalence of obesity either in terms of overweight or overfatness (Monyeki et al., 1999a). These results are similar to what was reported previously in other studies in

Africa (Cameron, 1991; 1992; Monyeki et al., 1995). In these studies tracking of poor nutritional conditions was not examined owing to the fact that the studies were cross-sectional.

It is a known fact that rural children of South Africa are malnourished and are inferior in growth compared to urban children, particularly at an early age (Walker & Walker, 1977; Richardson, 1978; Cameron et al., 1988; 1992; 1998; Cameron, 1991; Steyn et al., 1992; Monyeki et al., 1995). The duration and timing of the poor growth pattern of African children has hardly been investigated. An investigation of tracking anthropometric indices for malnutrition and physique in the Ellisras longitudinal study will shed more light on the physical growth and health status of children in a developing country.

2.3 Assessment of nutritional status from anthropometry

Anthropometry is widely used to monitor infant growth and to estimate child nutritional status. There are several goals related to anthropometry (De Ridder, 1999). They include the detection of either a reduced or an excessive growth rate, an increased failure- to-thrive, an assessment of human milk or substitute intake adequacy, an assessment of the appropriate age to introduce complementary foods, an evaluation of the adequacy of a weaning diet, an assessment of illness impact and response to treatment, a screening for high risk individuals needing special care, and an assessment of the response to counselling for improved feeding and other health-related practices (WHO, 1995).

In anthropometry, arm circumference and triceps skinfold thickness are often used to exhibit malnutrition in an individual or population (Jelliffe, 1966; Beaton et al., 1990; WHO, 1995; Steyn, 1999). Upper arm circumference (Beaton et al., 1990) and weight in relation to height (Burgent et al., 1979) can assess protein calorie malnutrition. The triceps skinfold thickness provides an estimate of body fat and the arm muscle circumference, which is calculated from the triceps skinfold thickness and the upper arm circumference, provides an indication of muscle mass (Jelliffe, 1966; Norton & Olds, 1996). Jelliffe (1966) developed norms, for adults of 25 years and older in which values of arm circumference and triceps skinfold thickness less than 60 percent of the reference standards indicate severe depletion of protein-calorie reserves.

Height and weight are predominantly used to assess the nutritional status of either an individual or a population (WHO, 1983; Cameron, 1991). The derived anthropometric indices from height, weight and age are expressed in terms of weight-for-age (WA), weight-for-height (WH) and height-for- age (HA), percentiles or percent of median. The z-scores (or standard deviation score) is the deviation of the value for an individual from the median value of the reference population, divided by the standard deviation for the reference population (WHO, 1983).

Z score = (Observed value – Median of the reference value)/ Standard deviation of the reference population.

A fixed z-score interval implies a fixed height or weight difference for children of a given age (WHO, 1983). A major advantage of this classification system is that for population based applications it allows the mean and standard deviation for a group of Z-scores to be calculated. A *Percentile* is the rank position of an individual in a given distribution, stated in terms of what percentage of a given reference distribution the group or the individual equals or exceeds. Thus a child of a given weight whose weight falls in the 10^{th} percentile weighs the same or more than 10 % of the reference population of children of the same age (Monyeki, 1999). *The Percent of the median* refers to the ratio of measurement value in the individual, for instance weight, to the median value of the reference data for the same age or height expressed as a percentage. The derived anthropometric indices can be used to compare the health status (stunting or wasting) of a child or a group of children with a reference population (Beaton et al., 1990). Stunting (lower height-for-age) reflects chronic malnutrition and wasting (lower weight-for-age and weight-for-height) indicates acute malnutrition in children (Beaton et al., 1990).

The growth reference curves developed by the US National Centre for Health Statistics (NCHS) and Centre for Disease Control (CDC), using data from the Fels Research Institution, are currently recommended by the World Health Organisation (WHO) for growth monitoring and nutritional assessment (WHO, 1986; Dibley et al., 1987). The WHO recommended the WH as an indicator of present nutritional status and HA as an indicator of underweight (Martins & Menezes, 1994). WH is approximately independent of age between 1 and 10 years and it is relatively independent of ethnicity, particularly in the age group between 1 and 5 years (Waterlow et al., 1977; Cole, 1991). WA is used in populations where accurate age information but not height measurements are available (Martins & Menezes, 1994). In this case it is difficult to determine whether a lack of growth is a result of inadequate weight gain, an inadequate growth in height, or both (Waterlow et al., 1977; WHO, 1986; Gorstein et al., 1994). Cole (1979) used the following formula to determine the WH:

Height-for-age = child's actual height/ expected height of the child
Weight-for-age = child 's actual weight/ expected weight of the child
Where expected weight or height of the child is the 50th centile at any age.

Weight for Height = actual weight-for-age/ (actual height-for age)^2.

Chinn and Morris (1980) have argued that Cole's (1979) method of assessing WH will lead to errors in the assessment of English children, and to a lesser extent to Scottish children, especially to children taller for their age, whose WH will be overestimated. The United States Health and Nutritional Examination Survey (NHANES III) provides reference data for black Americans aged 1 to 74 years (Frisancho, 1990), which indicate that anthropometric values below the 5th percentile imply nutritional depletion. Gibson (1990) validated the use of Z-score values of less than –2 for height-for-age and weight-for-height to determine the prevalence of stunting and wasting, respectively.

Nutritional anthropometry poses a problem. A standard is needed to compare a single person with a group in order to assess individual nutritional status. Furthermore, the question of whether or not all child populations in the world have the same genetic potential for growth in size is still unresolved (Martins & Menezes, 1994). The CDC/WHO reference curves for WA, WH, and HA are now widely used throughout the world and provide a guideline to estimate childrens' nutritional status. There is a long running debate on whether, in a particular country, it is preferable to use an elite standard derived from the group in the population that is better off, or to use a more randomly chosen group free from malnutrition, infection and parasites (Waterlow et al., 1977; Tanner, 1962). Nevertheless, current evidence suggests that present reference values are not adequate for the use of all infants, especially those who live under favourable conditions (WHO, 1995). Nowadays, researchers in Sub-Sahara use The United States Health and Nutritional Examination Survey (NHANES I, II and III) reference data developed by Hamill et al. (1979) and Frisancho (1990), even though they have some shortcomings. Cameron et al. (1998) reported low weight-for-height in African children and concluded that the children were generally distinguished from European children by a "tendency towards lower weight-for-age at a given height". Hence a special nutritional norm for African children is necessary.

Different anthropometric cut-off points have been used in nutritional surveys to estimate the severity of protein energy depletion in children, but controversy still exists as to what reference standards to use (Harries et al., 1985). The internationally accepted cut-off point for low birth weight is 2.5kg (Cameron, 1991). Children born below this weight are known to have a high risk of morbidity and mortality during the first five years of life and particularly during the first year. Shapiro et al. (1980) has found that low-birth-weight infants are almost 40 times more likely to die in the neonatal period than normal-birth-weight infants are.

Studies in South Africa have shown that on the basis of Boston-Iowa reference standards (Nelson et al., 1969) from half to three quarters of blacks, coloured and Indian school children, at pre-puberty and early adolescence, lie under the 3rd percentile of weight-for-age reference data (Richardson, 1977; Walker, 1978). This implies that these children attain 80 percent or less of the 50th percentile of weight-for-age accordingly. The proportions mentioned are classified as suffering from protein-energy malnutrition (mild, moderate and severe). Similar information on less privileged populations has been published from other countries in Africa e.g. Zambia (Goldin & Barclay, 1972), Botswana (Corlett, 1986), Lesotho (Ruel et al., 1990) and Uganda (Vella et al., 1992; Cortinovis et al., 1997). Socio-economically, Black South African school children are less favourably placed than those of other ethnic groups since they have more than 80 percent of the appropriate weight-for-height less than the 50^{th} percentile of the reference standard (Walker, 1978).

A recent report indicates that in Africa 38.6% of pre-school children are stunted and 27.4% are underweight for age (De Onis et al., 1993), thus 44.6 million children are stunted and 31.6 million are underweight (Visschedijk & Simeant, 1998). The highest prevalence of stunting and underweight are found in East Africa, 47.0% and 31.0%, respectively and in west Africa, 37.9 and 32.8% respectively (Steyn, 1999; Steyn & Walker, 2000). The prevalence of stunting and wasting are lower in Northern Africa, where they are 25.4 and 11.3%, respectively. While there are limited data in Southern Africa, statistics indicate that the prevalence of stunting lies between 22.9 and 30.3% and underweight between 9.3% and 26.2% (Steyn & Walker, 2000). Labadarios and Van Middelkoop (1995) have reported the lowest percentage of stunting and underweight (29.9% and 9.3%, respectively) in South African pre-school children.

Much of our knowledge about growth of children in the developing world and especially in Africa is based on information from cross-sectional studies. Cameron (1991) has shown that more than 60% of black South African children fall below the 50th centile of the NHANES I and II sample (Hamill et al., 1979). A recent survey by Steyn et al. (1992) and Monyeki and Toriola (1997) in the Northern Province of South Africa indicated that stunting and low weight-for-age were present in more than 30% of pre-school Pedi children aged 3 to 5 years and Molepo children aged 8 to 14 years, while 37% was reported in Kenya, 23% in Lesotho and 30 % in Swaziland for the representative sample of rural areas (Haaga et al., 1986; National Nutrition Council, 1985; Government of Lesotho/ USAID, 1976). In nutritionally impoverished children the growth spurt lacks vigour, producing delay in timing, lowered velocity and consequently stunted adult height (Cameron, 1991). Martorell (1989:19-20) maintained that "... *it is a travesty to call the process of stunting healthy since its causes are deficient diets and* *infection... Good growth means good health... A society in which major proportions of its children are stunted is one with serious public problems.... ".*

The use of anthropometric indices derived from reference standards is appropriate for many purposes, but for protein-energy-malnutrition there are better ways of adjusting anthropometric values for age and sex, such as through multivariate analysis (Armitage & Berry, 1987) or residual analysis (Esrey et al., 1990). However, these methods are generally more suitable for research applications. It is vital to note that in all indices derived from age—specific reference data, their precision depends on the exact knowledge of the age when this information is available (Lindren & Cernerud, 1992). The use of age-based indices such as height-for-age may, therefore, result in misclassification and the number of repeated measurements carried out on the same person together with the period between two measurements (Kemper, 1985; Twisk et al., 1994). However, the suitability of these anthropometric cut-off points for the diagnosis of malnutrition in developing countries is controversial (Harries et al., 1985; Monyeki & Toriola, 1997). The pattern of wasting and stunting among African children seems to be high even though they can not be regarded as a true reflection of a nutritional deficiency or of a genetic difference in physique (Cameron, 1991), given the diversity of the socio-economic and living conditions of black African people across the continent. A thorough longitudinal investigation will give substantial evidence on the timing and duration of the poor nutritional conditions of children in developing countries.

2.4 Socio-economic status of rural South African children

Protein-energy malnutrition among pre-school and primary school children remains a major cause of morbidity and mortality in developing countries (Haaga et al., 1985; Van Den Broek et al., 1993). A combination of low educational level, poor standards of hygiene and sanitation, low household income and demographic factors, such as low maternal age, or small birth interval, are often reported to be the major causes of malnutrition in developing countries (Haaga et al., 1985).

The existence of social disparity in the health of the child has been shown in many studies (Chamberlain & Simpson, 1979). Social status is related to the stature of the population that reflects the difference in average well being and nutritional status between classes and between dwelling areas. Data of eighteen century German boys give evidence of the relationship between secular changes in socio-economic conditions and height (Komolos, 1990). Attained height at different ages is still a sensitive indicator for the health status of children, especially in developing countries (Preece, 1989). Meredith (1984) has extensively studied differences in the body size of infants and children in relation to socio-economic status in a number of developing and developed countries. His study shows that weight and height differs strongly between socio-economic groups, and that these differences are larger in developing and poor countries.

Africa's lack of industrialization and absence of socio-economic and social changes have meant that the studies on growth and development of African people are few in number. Eveleth and Tanner (1976) listed 26 studies covering the period 1949 to 1972, investigating the growth of African children throughout the continent. The areas covered by these studies were from Rwanda (Hiernaux, 1964), Sudan (Sukkar et al., 1971), Tanzania (Hautvast, 1971), Uganda (Rutishauser, 1965), Malawi (Burgess & Wheeler, 1970) and South Africa (Smit et al., 1967). Eveleth and Tanner (1976 & 1991) emphasized that the most striking features of the growth pattern commonly illustrated by these studies are the effects of malnutrition and disease that mask the underlying growth pattern.

Growth rates in the first year of life have been investigated intensively in developing countries (Cameron et al., 1998). Richardson (1977) studied 1036 babies in Johannesburg and showed a lack of significant difference between their mean height. Mean weights of girls were not significantly different but Colored and Indian boys were significantly lighter by one year. Growth patterns begin to diverge during the second year of life when feeding patterns and regimes are well established (Richardson, 1977). The cause of these characteristic patterns is usually explained in the light of weaning patterns. However, if the child is breast-fed he grows at a rate comparable to growth rates of children from developed countries. As soon as weaning is complete, the effect of the adverse nutritional and health environment becomes manifest in the child, with a consequent loss of growth rate, until it falls within a zone of growth adaptation (Cameron, 1991). At this point below the NCHS 5th centile, chronically low nutritional intake is manifested by a less than average growth rate, because there is less energy available from the diet to allow normal growth rates (Steyn et al., 1992).

It is important to measure socio-economic variables to assess their impact on variability in growth patterns (Tanner, 1962). Fluctuations in the rate of growth of children associated with fathers' occupation and family income are well documented in the Northern Hemisphere (Tanner, 1962; Bogin et al., 1990). In South Africa, urban black school children from families of high socio-economic status were reported to be well nourished compared to those of lower socio-economic status (Walker & Walker, 1977). Recently, studies on the overall physical growth changes of rural children of South Africa by Monyeki et al. (1995), Steyn et al. (1992), Monyeki and Toriola (1997) and Kekana and Monyeki (1998) clearly depicted that rural children consistently exhibited poor growth. However, the specific roles played by individual socio-economic factors on the growth of the children were not highlighted. An assessment of the intensity with which various socio-economic factors, like family income, number of siblings in the family, dwelling conditions, smoking habits, etc., influence human growth, producing variation between individual growth need to be investigated. In South Africa, urban black school children from families in the high socio-economic bracket were reported to be well nourished compared to those with lower socio-economic backgrounds (Walker & Walker, 1977).

It is apparent that the patterns of human growth found amongst African children, as illustrated by the growth patterns of South African black children, demonstrate the environmental impact associated with the developing nature of the continent. Considering the diversity of growth patterns that emerge in the second year of life, which is absolutely related to poor environment and socio-economic conditions, it is not evident whether this trend continues to adulthood.

2.5 Somatotype

2.5.1 Somatotyping -A brief history

The principle of classifying human physique has enjoyed a high status in the history of man from as early as the fifth century BC (Sheldon et al., 1940:10; Tucker & Lessa, 1940:411-455). Already during the fifth century BC, Hypocrites described people with long thin bodies dominated by the vertical dimension as "habitus phthisicus" and those with short thick bodies, strong in horizontal dimension, as "habitus apoplecticus". In the fourth century BC, Aristotle noted that a specific body always designated a specific character.

In the first century AD Celsus wrote about why some people are fat and some thin. Rostan, in 1828, described three types of human physique: "type digestive", "type muscular" and "type cerebrale". Rostan, however, did not invent this terminology. The Frenchman, Halle, had used it as early as 1797. In 1869 Samuel Wells classified the human body as a "motive temperament", a vital or "nutritional system" together with a "mental or nervous system". He said that the "motive temperament" is marked by superior development of the osseous and the muscular system, forming the locomotive apparatus of the body. The "vital temperament" - the principal seat of which is in the trunk, gives tone to the organization of different body parts while the mental system exerts the controlling power (Carter & Heath, 1990).

The development of anthropometry added a new dimension to the study of morphology (Sheldon et al., 1940:13; Carter & Heath, 1990:9). Late in the nineteenth century Di Giovanni conducted an anthropometric study in the school of clinical anthropology (Petersen, 1967:99; Tittle & Wutscherk, 1972). His pupil, Viola, differentiated between three different types of human physique. This research referred to subjects with large, heavy bodies and relatively short limbs as "macro-splanchnic", those with a small trunk and relatively long limbs as "micro-splanchnic" and those with intermediate variation as "normo-splanchnic". In 1880, Huter (Carter & Heath, 1990:4) classified human beings as "cerebral", those with a predominant ectodermic structure, "muscular", those with predominant mesodermic structure and "digestive", those with predominant endodermic structure. In "Korperbau und charakter" (1921) and Ernst Kretschmer (1888 - 1964) the four physical body types are described (i.e. "Athletics", "Pyknic", "Asthenic" and "dysplastic physique"). Later he substituted the word "leptosomic" for "asthenic" and made a distinction between the linearity and the slender fragility and gracility of the leptosomic type.

According to Tucker and Lessa (1940:265-289), Sheldon's somatotype concept of continuous variation was an improvement on the systems of classification mentioned above, especially in the early 20th century. Sheldon recognized that every individual consists of a mixture of all three basic components. These components vary in different degrees in an individual. The three components were called "pyknosomic", "somatosomic" and "leptosomic", but later substituted with the terms endomorphy, mesomorphy and ectomorphy (Carter & Heath, 1990:13).

The characteristics of the human physique, which are associated with success in sports and other forms of physical performance, have always interested scientists. The number of studies using measurements or morphology of athletes has accelerated rapidly in the past century, and focused mainly on the description of sports relationship to physique, to physiology and to sports performance or sports anthropometry (Tanner, 1964:33).

Several researchers (Duquet et al., 1975; Stepnicka, 1976; Singh and Sidhu, 1980; Holopainen et al., 1984; Eiben, 1985) have used anthropometric somatotyping on children aged 6 to 10 years. Parizkova et al. (1984) used this method on children between the ages of 3.5 and 6 years, while Amador et al. (1983) worked on children between the age of 1.5 and 5.5 years.

2.5.2 Methods of assessing physique

Anthropometric dimensions used individually and relative to each other in the form of proportions are commonly used to make inferences about physique. An individual may generally be described as having relatively short legs or broad shoulders. Although ratios and indices derived from various combinations of anthropometric dimension provide important information, they have certain limitations. For instance, when used alone they are neither adequate nor accurate indicators of physique (Malina & Bouchard, 1991:66).

The Heath-Carter photoscopic somatotype ratings are based upon the standard somatotype photographs, together with a record of age, present height and weight of the subject. Accurate ratings depend upon skill in recognizing the probable ratings for each component and in reconciling photoscopic impression with appropriate somatotype. The Heath-Carter anthropometric somatotype method allows anthropometric measurements to be assessed as well as to distinguish between differences in a given subject's somatotype components. Furthermore, it provides an objective starting point for an anthropometric and a photoscopic rating when a photograph is available. The Heath-Carter method provides the data for reliable somatotype ratings when minimal clothing is desirable. Measurements can be used for other analyses as well as evaluation of body structure and somatotype ratings (Carter & Heath, 1990:367).

2.5.2.1 Sheldonian somatotype

Sheldon's approach for assessing physique is commonly used in the whole world today (Meredith, 1940:301-309). Sheldon's method is basically photoscopic. It is based upon the principle that the entire body conforms to three components, namely endomorphy or the first component - characterised by the predominance of the digestive organs, the softness and the roundness of contour throughout the body. Mesomorphy or the second component - characterised by the predominance of muscle, bone and connective tissue or (musculo-skeletal robustness relative to stature and weight). Ectomorphy or the third component is characterised by the linearity and fragility of build with poor muscular development or relative linearity (Carter & Heath, 1990:352; Malina & Bouchard, 1991:66).

Each component of the physique is assessed individually. Ratings are based on a 7- point rating scale, with 1 representing the smallest expression, 4 representing a medium expression and 7 representing the fullest expression (Malina & Bouchard, 1991:66). A component rating is always recorded together with the other two components in order to ensure that the somatotype meaning is not lost. For example 7-1-1 (extreme endomorphy), 1-7-1 (extreme mesomorphy) and 1-1-7 (extreme ectomorphy). The first number always refers to endomorphy, the second to mesomorphy and the third to ectomorphy (Carter & Heath, 1990:353; Malina & Bouchard, 1991:67).

The assumption in this method is that an individual's somatotype does not change with age, nutritional state, or state of physical training. It is developed on adult males. Therefore, the change in somatotype during growth is not a factor. This method has been applied to children but with limited success (Heath, 1963:227-233; Sheldon et al., 1969:839-911).

2.5.2.2 Modification of Sheldon's method

2.5.2.2.1 Parnell's Phenotype method

In modifying Sheldon's method, Parnell (Parnell, 1954; Carter & Heath, 1971) incorporated several anthropometric dimensions to derive a phenotype, which is defined as a physique at a given point in time. Stature, body mass, three skinfolds, two limb circumferences and two bone widths were used to calculate the three components, namely fat (F), muscularity (M) and linearity (L), resembling Sheldon's endomorphy, mesomorphy and ectomorphy component, respectively (Malina & Bouchard, 1991:68).

2.5.2.2.2 Heath-Carter somatotype method

The Heath-Carter somatotype method is a modification of the system developed by Sheldon and his colleagues. It uses much of the original vocabulary and employs the criteria of their basic approach which are objective and straight forward. The fundamental modifications are as follows (Hebbelinck & Ross, 1974; Ross et al., 1974): The somatotype rating is a phenotype rating, which allows for changes over time. The rating scales for the three components are open and redefined so as to apply to the physique of both sexes at all ages. Selected anthropometric ratings help to objectify somatotype ratings.

Endomorphy -first component - or (relative fatness or leanness) is derived from the sum of the three skinfolds, triceps, subscapular and supraspinale skinfolds.

Mesomorphy -second component - (relative musculo skeletal) is derived from the humerus and femur width, flexed arm girth, corrected for the thickness of the triceps skinfolds and calf girth, corrected for the thickness of medial girth. These four measurements are adjusted for stature. Carter and Heath (1990) view this second component as expressing fat-free mass relative to stature.

Ectomorphy -third component - (relative linearity of build). It is based on stature divided by the cube root of the body weight.

Each component contributes variably to somatotype, hence it is relative fatness, relative musculo-skeletal and relative linearity in reference to the physique which is a composite. Although the three components are related, they are conceptually and methodologically quite different (Carter & Heath, 1990:367-374; Malina & Bouchard, 1991:69).

2.5.3 Somatotyping children

From the research done by Tanner and Whitehouse (1982) it is evident that from the age of 3 or 4 to 8 years a child's somatotype changes dramatically as a result of growth. These changes most likely reflect the distribution of subcutaneous body fat, development of muscle tissue and the lengthening of the legs relative to stature. During adolescence the most conspicuous growth change in children are the relationship between the shoulder and the hip width (Roche & Malina, 1983), together with the accumulation of subcutaneous fat in girls and the development of muscles in boys (Malina et al., 1988; Malina, 1989). Although somatotype changes occur during growth they are generally not dramatic in most children.

2.5.3.1 Distribution of somatotype

According to Petersen (1967) differences in physique between boys and girls are apparent in the distribution of somatotype seen in large samples of children. The physique of endomorphic males and females or mesomorphic males and females are similar (Malina & Bouchard, 1991:77), although there are more endomorphic girls and more mesomorphic boys which represent the genetic origin (i.e. in a large sample of children, there will be more endomorphic girls than boys, and more mesomorphic boys than girls).

In plotting children on the somatochart, Tanner and Whitehouse (1982) found that although most children tend to have a balanced physique, girls dominated the endomorphy sector more than boys did, while boys dominated the mesomorphy sector.

Petersen (1967:34) found that with somatotyping, sex differences centred primarily on endomorphy and mesomorphy. On average, from pre-school age through to young adulthood males are more mesomorphic, slightly more ectomorphic and less endomorphic than females (Tanner & Whitehouse, 1982). According to these researchers females are consistently more endomorphic than males.

2.5.3.2 Changes in somatotype during growth in boys

Table 2.1 summarises the findings of longitudinal studies on the somatotypes of boys. The means given in Table 2.1 indicate that males tend to become more mesomorphic with age. Zuk (1958) was the first researcher to use the longitudinal study method in somatotyping Californian boys between the ages of 12 and 17 years.

Morton's (1967) report on Medford boys between the ages of 9 and 16 years indicates that the mean somatotype of each age group clustered at about 3-4-3 in the upper central region of the somatochart, with a moderate south-eastern clustering on the somatochart, which showed a tendency towards an increase in ectomorphy.

TABLE 2.1: LONGITUDINAL STUDIES OF THE MEAN SOMATOTYPES OF BOYS BY AGE

REFERENCE	SAMPLE AND METHOD	N	AGE IN YEARS	SOMATOTYPE Endo-meso-ecto
Parizkova et al. (1984)	Prague infants, Czechos-Lovakia (anthro-pometric)	28 28 28 28 28	3.5 4.0 4.5 5.0 6.0	3.3-5.7-0.9 3.2-5.6-0.9 3.0-5.4-1.2 2.6-5.2-1.7 2.6-5.0-2.2
Parizkova and Carter (1976) Carter and Parizkova (1978)	Prague boys, Czechos-lovakia, (Athro-pometric)	39 39 39	10.7 11.7 12.7	2.5-4.1-3.4 2.4-3.9-3.6 2.1-4.0-3.6
Zuk (1958)	Oakland, California(photo-scopic)	74	12	3.2-3.3-3.9
Heath and Carter (1971)	Manus, Admiralty Island. (Photo-scopic)	15 12 15 25 24 20	2 4 6 8 10 12	3.9-5.0-1.0 3.6-5.0-1.2 2.1-5.0-1.4 1.5-5.1-2.1 1.9-5.1-2.3 1.7-5.0-2.8
Clarke (1971)	Medford, Oregon. (Photo-scopic)	106 106 106 106	9 10 11 12	3.4-4.2-2.9 3.6-4.2-2.9 3.4-4.2-3.2 3.5-4.1-3.2
Hebbelinck et al. (1995)	Leuven, Belgium Anthropometric	52 52 52 52 52 52 52	6 7 8 9 10 11 12	2.1-4.2-2.6 2.0-4.1-3.0 2.0-4.1-3.3 2.1-4.0-3.5 2.2-4.0-3.6 2.3-3.9-3.7 2.4-3.9-3.8
Carter et al. (1997)	Saskatchewan, Canada Anthropometric	63 63 63 63 63 63	7 8 9 10 11 12	2.9-3.6-1.6 2.7-3.6-2.0 2.7-3.5-2.3 2.6-3.6-2.6 2.7-3.7-2.9 2.7-3.7-3.1

Heath and Carter (1971) somatotyped Manus Island boys between the ages of 2 and 22 years, and found that from the age of 2 to 8 years males' endomorphy decreased while their ectomorphy increased. From the age of 8 to 14 years mesomorphy in the males decreased slightly while ectomorphy increased. From the age of 14 years mesomorphy increased in males with a mean somatotype of 2-6-1.5 at the age of 20 years.

A study done by Toteva (1986) on 7-year old Bulgarian boys, who were followed for one year, showed that mesomorphy increased and ectomorphy decreased slightly. The mean somatotype for boys was 2.5-4.5-3. These studies indicate that boys increase in mesomorphic and ectomorphic ratings throughout the ages (2 to 22 years) while the endomorphic rating remains constant.

Recently Hebbelinck et al. (1995) and Carter et al. (1997) have summarised the stability of both Saskatchewan and Belgian boys as follows:

- Mean somatotype shows consistent patterns of overall change from 7 to 16 years in both samples.
- The change is from endo-mesomorph through central to mesomorph-ectomorph. Mesomorph and ectomorph account for the most changes in the Saskatchewan boys.
- The somatotype of the Belgian boys changed in childhood from ecto-mesomorph to ecto-mesomorph and to more extreme ectomorph-mesomorph by late adolescence.
- Migratory distance showed that the somatotype of a few children is quite stable while that of many others is extremely variable with changes of 3 to 4 times greater than the most stable Belgian boy, and 2.9 to 10 for the Saskatchewan boys.
- The inter-age partial correlations for each component are high between adjacent years and are lower as differences between years increase.
- There appears to be no period in which the somatotype for Belgian boys is predictable for boys from 6 to 17 years while in the Saskatchewan boys the longer the period the poorer the predictability.

2.5.3.3 Change in somatotype during growth in girls

Zuk (1958) was the first to use the Heath-Carter ratings to collect longitudinal data on girls. He reported the somatotype of 78 Californian females between the ages of 12 and

17 years. He found that with increasing age, females tend to become more endomorphic (cf. Table 2.2) than boys.

In somatotyping Manus Island girls, Heath and Carter (1971) found that the mean somatotype of girls was similar to that of boys of the same sample between the ages of 2 and 12 years.

TABLE 2.2: LONGITUDINAL STUDIES OF THE MEAN SOMATOTYPE OF GIRLS BY AGE

REFERENCE	SAMPLE AND METHOD	N	AGE IN YEARS	SOMATOTYPE endo-meso-ecto
Zuk (1958)	Oakland, California(photo-scopic)	78	12	3.9-3.3-3.5
Heath and Carter (1971)	Manus, Admiralty Island, (photo-scopic)	11 13 12 31 21 13	2 4 + 5 6 8 10 12	4.3-4.5-0.9 2.8-4.5-1.5 2.5-4.4-1.5 2.0-4.5-2.3 2.1-4.3-2.9 2.5-4.3-3.1
Parizkova et al. (1984)	Prague infants, Czechoslovakia, (anthropometric)	28 28 28 28 28	3.5 4.0 4.5 5.0 6.0	3.7-5.2-0.7 3.4-5.4-0.9 3.4-5.4-1.1 3.4-5.1-1.3 3.2-4.5-2.0
Hebbelinck et al. (1995)	Leuven, Belgium Anthropometric	30 30 30 30 30 30 30	6 7 8 9 10 11 12	2.8-4.4-2.3 2.7-4.2-2.8 2.8-4.1-2.9 2.9-4.0-3.1 3.1-3.9-3.3 3.1-3.9-3.5 3.0-3.8-3.5

The mean somatotypes for girls and boys between the ages of 2 and 6 years are close and their distribution overlaps. From the age of 8 years the somatotypes of males and females increase with greater disparity at the age of 16 years. Between the ages of 2 and 8 years endomorphy of males' decreases and their ectomorphy increase. From the age of 8 to 12 years the males' mesomorphy decreases slightly and their ectomorphy continues to increases.

Bok and Tlapakova (1982) somatotyped Czechoslovakian girls between the ages of 15 and 17 years. They found that with a mean somatotype of 4-3.5-3 at the age of 15 years and 4-4-2.5 at the age of 16 years girls tend towards an increase in mesomorphy and slight decrease in ectomorphy. Toteva (1986) in somatotyping 7-year-old Bulgarian girls, whom he followed for one year, found that mesomorphy increased and ectomorphy decreased slightly. Their mean somatotype was 3-4-3.

2.5.3.4 Stability of physique in children

Physique has been useful in assessing the outcomes of underlying growth and maturity processes, which leads to a better understanding of variation in both child and adult physique (Carter & Heath, 1990). The question of stability of physique throughout these processes has been investigated in only a limited manner in the Northern Hemisphere (Walker & Tanner, 1980; Bok & Tlapakova, 1982; Claessens et al., 1986; Malina & Bouchard, 1991; Hebbelinck et al., 1995; Carter et al., 1997), while in Africa it has hardly been reported. Carter and Heath (1990) showed the importance of examining patterns of individual children in addition to group averages. This is because some children changed in one direction while others changed in the opposite direction, thus confounding individual changes. Longitudinal studies on change of somatotypes provide valuable information on the somatotype stability. Carter and Heath (1990) and Hebbelinck et al. (1995) reported that both individual and group somatotypes change with age; individual patterns of change are important but may be masked by group variability. Longitudinal studies are needed to provide a better basis for understanding overall physique changes in growing children, since most of the studies on somatotype are cross-sectional. It appears that some children are fairly stable over a specific period in their growth (Bok & Tlapakova, 1982; Claessens et al., 1986; Carter & Heath, 1990).

In studies carried out on Belgian children, Duquet (1980) assessed the somatotypes of boys and girls aged 6-13 years and concluded that individual somatotypes were relatively stable but that there was a slight variation in the mean somatotypes of the group. Carter and Heath (1990) have finally summarized the model of somatotype as follows:

- In general, boys at younger ages move from endo-mesomorphy to ecto-mesomorph and balanced ectomorphy-mesomorphy. During adolescence, with increased muscle mass and complete ossification, mesomorphy increases and ectomorphy decreases.
- In general, girls, like boys, move from endo-mesomorph and balanced endomorphy-mesomorphy towards central somatotype. In adolescence, characterized by early maturity, they move towards balanced endomorphy-mesomorphy and meso-endomorphy.

Although there are genetic factors in the development of somatotype components, nutrition and exercise play an important role (Carter & Heath, 1990). The existence of a high prevalence of chronic and acute under nutrition (Monyeki et al., 2000) and lack of overweight or overfatness, was reported in a cross-sectional sample of Ellisras rural children (Monyeki et al., 1999a). The need to assess these children over a six-month interval was important even though somatotypic differences in adjacent years were often reported to be small. Differences are evident at two-year or more intervals (Carter & Heath, 1990).

2.5.3.5 Somatotype and Nutrition

The effects of drastic nutritional deprivation on somatotype were investigated by Ancel Keys as part of the Minnesota Starvation Experiment as early as 1944 (Carter & Heath, 1990). The effects of partial starvation on somatotype of 34 males were examined by Lasker (1947) who uses both Sheldon's photoscopic and anthropometric somatotype methods.

Lasker (1947) showed that partial starvation had the effect of decreasing endomorphy by 47%, mesomorphy by 43% in the 34 subjects. Ectomorphy increased by 77%. In general predominantly endomorphic individuals had declined in endomorphy and mesomorphy whereas ectomorphy had changed slightly. De Wijn (1965:500) in investigating 37 Dutch boys found that somatotype was not independent of the state of nutrition and that particularly in puberty, ectomorphy actually may mean a great deal of underdevelopment of muscles and the subcutaneous fat layer. Smit (1968), in investigating Coloured and Indian South African populations, found that the incidence of greater ectomorphy in this population may be related to under-nutrition. Even though studies on somatotype and nutritional status of children are limited they generally concluded that environmental factors do affect morphology as reflected in somatotype. Lasker (1947) also concluded that somatotyping serves better as a measure of nutritional status than as a measure of inherent tendencies to specific constitutional types.

It is a well known fact that black children in South Africa are more ectomorphic (Smit, 1968; Walker, 1978; Monyeki et al., 1994; Monyeki et al., 1999b). However, the duration and the timing of these tendencies of black children to be predominantly in the ectomorphic sector, were hardly investigated. A thorough investigation of this relationship will shed more light on the phenomenon.

2.6 Summary

To date, anthropometry is the most important tool to screen physical growth and health status of children in the whole world. The WHO has recommended both the NCHS and NHANES I, II and III standards to be used in screening malnutrition on the African continent.

The level of malnutrition in Africa ranges from 15 to 30% in both representative samples of rural areas of Lesotho, Zambia and Malawi. In South Africa the prevalence of malnutrition is high in the rural areas and is above 25% compared to urban areas. Children from a high socio-economic background are less affected by malnutrition. Even though most studies have shown that the prevalence of malnutrition is high in rural areas they have not exhibited the duration and timing of malnutrition since most studies were cross-sectional.

In general boys at younger ages move from endo-mesomorph to ecto-mesomorph and balanced ectomorphy mesomorphy while younger girls further move to central somatotype. Differences in growth of physique of children who are associated with malnutrition were reported to be mesomorphic ectomorph and balanced ectomorph. Some children have a relatively stable somatotype throughout their life span. The stability of the somatotype of African children has never been investigated in Africa.

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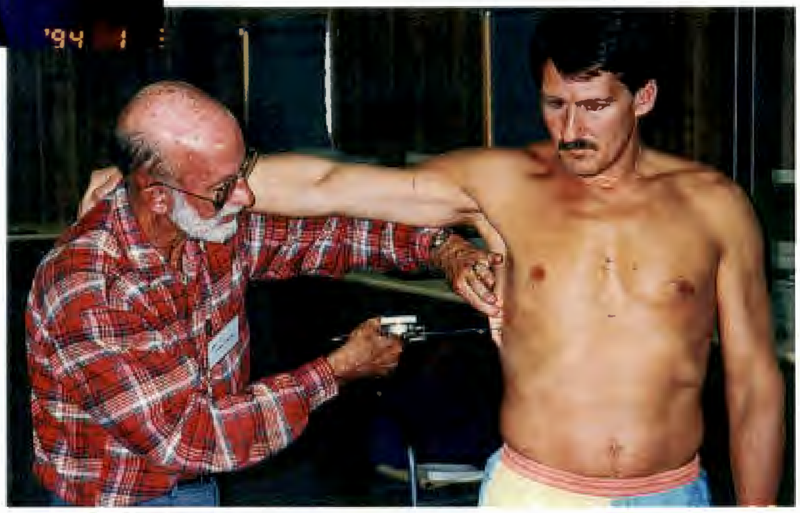

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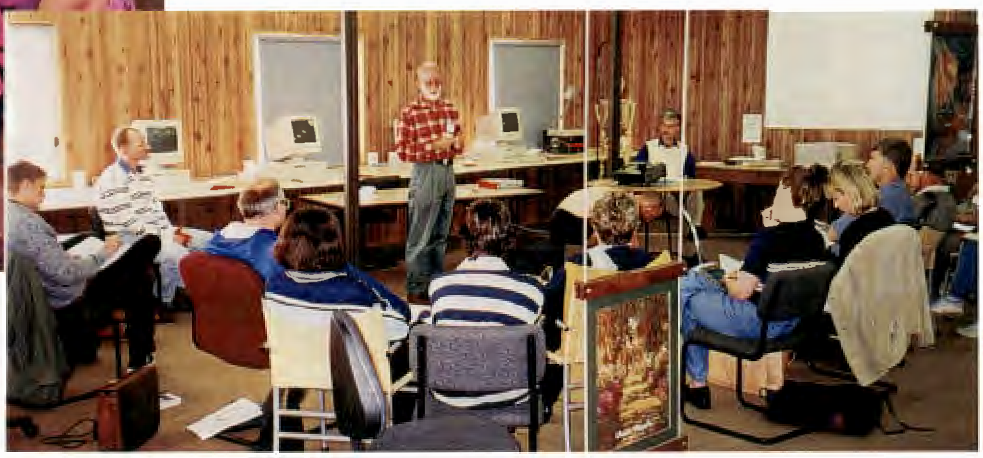
Dr Tim Olds
Mr James Dollman
} *University of South Australia Australia*



3

THE GROWTH AND NUTRITIONAL STATUS OF RURAL South African CHILDREN AGED 3 - 10 YEARS OLD: THE ELLISRAS GROWTH STUDY

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ABSTRACT

This study presents cross-sectional data from an ongoing mixed-longitudinal study of growth of rural children from Ellisras, South Africa. The physical growth and nutritional status of 1,335 children (684 boys, 651 girls), 3-10 years of age, was determined using standard anthropometric techniques. Weight-for-age, height-for-age and weight-for-height were expressed as Z-scores of the NHANES I and II or NCHS reference sample. A Z score of less than –2 was used as the cut-off point to determine the prevalence of stunting and wasting. Mean heights increased parallel to 50th centile up to 6 years of age, thereafter both sexes diverged from the NHANES reference by approximately 0.5cm per year. Mean weight follow a more consistent pattern from 3-7 years for both sexes, which was parallel to just below the 10th centile, but diverged between 8 and 10 years of age. Z-scores of weight-for-height in both sexes varied between –1 to –2 through-out the age range and BMI values were lower than the 5th centile of NHANES, indicating a significant amount of wasting within the sample. The sample exhibited a high prevalence of stunting, rising from less than 10 % at 7 years to more than 30% by 10 years of age. Increments of the mean heights and weights indicate that the effects of stress may be a gradually accumulating process and that the growth increments of these children became increasingly poor in contrast to those of the reference sample. Since stunting in childhood is permanent, it may lead to a loss of physical work capacity in adulthood. Therefore, further investigation of the cause of poor growth among these rural children is imperative.

Key words: growth, nutritional status, children, anthropometry, South Africa, rural, sex differences

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INTRODUCTION

Almost 50% of the South African black community live in rural areas (Van der Merwe, 1988). The growth patterns of children of these rural communities have been well documented during the past two decades (Cameron, 1991; Cameron, Kgamphe, Leschner and Farrant, 1992; Cameron, De Wet, Ellison, and Bogin, 1998; Monyeki, Pienaar and De Ridder, 1995; Steyn, Badenhorst, Nel and Jooste, 1992; Richardson, 1978; Walker and Walker, 1977). Because of the need to evaluate nutritional status to guide intervention programmes, many of the earlier studies focused on the growth and development of children during the first five years of life. Later, interest in adolescence and pubertal development led to further studies aimed specifically at older children. These studies revealed that such children exhibit high prevalences of stunting in infancy and delayed adolescent growth compared to their urban peers. However, it is not always the case that urban environments result in an improved growth status. The high urbanization rate in South Africa (Van der Merwe, 1988) with a consequent rapid increase in the size of urban areas, has resulted in large areas of informal housing and an inferior growth status of the children of these informal urban communities in comparison to their rural peers (Cameron et al., 1992).

Whilst most studies have been conducted on infants and adolescents, the time period between infancy and adolescence has received less attention, even though it represents an important psycho-social and physical transitional period in the life of the child. For the majority of children, it marks the end of total dependence on the mother and the first interaction with a wider community through formal schooling. In situations in which meals are provided at school this may also represent a time of *nutritional* change to a more varied and perhaps less stable diet.

The desire of the new South African government to improve the health of rural peoples requires that adequate baseline data are available to evaluate the effect of improved nutritional and health care. The current study was designed as a mixed-longitudinal study to investigate the growth and nutritional status of rural children attending formal pre-primary and primary schools in rural area of South Africa. Such children are within the 3 to 10 year age group and thus form a legitimate target population to add detail to previous information on infants and adolescents. The purpose of this report is to present initial cross-sectional data on the physical growth and nutritional status as indicated by height-for-age, weight-for-age and body mass index (BMI).

MATERIALS AND METHOD

Geographical location

The participants for the study were 1335 children (684 boys, 651 girls), 3 - 10 years of age, from rural villages situated within the northwestern area of the Northern Province of South Africa. These villages, approximately 70km from the provincial town of Ellisras (23° 40S 27° 44W), are adjacent to the Botswana border. The Iscor coal mine and Matimba electricity power station are the major source for employment for many of the Ellisras rural residents, whereas the remaining workforce are involved in subsistence farming and cattle rearing, and a minority in education and the civil service.

Sampling

The study was undertaken at 22 schools (10 pre-school and 12 primary schools) randomly selected from a total of 68 schools within the Ellisras area. Birth records were obtained from the principals of each school. Only those birth records that had been verified against health clinic records were used to determine the age of each potential participant. Each of the 22 chosen schools was assigned an age category (i.e. 3,4,...9,10), and only children whose verified age was within the category for a particular school were assessed. Sample sizes by age ranged from 14 to 199 for boys and 17 to 174 for girls. Sample sizes per age group fluctuated within and between genders because within each school there were different numbers of children of the designated age.

Anthropometric assessment

All children within the selected age group underwent a series of anthropometric measurements of height, sitting height, weight, arm span, trochanteric height, circumferences (head, neck, ankle, calf, thigh, gluteal, waist, chest, wrist, forearm, upper arm both flexed/relaxed), breadths (bi-acromial, bi-iliac, transverse chest, A-P chest, bi-epicondylar humerus and femur) and skinfolds (triceps left and right, biceps, subscapular, supraspinale, abdominal, front thigh, medial calf) according to standard procedures (Cameron, 1984).

The survey was carried out over a three-week period by 16 anthropometrists, who were required to undertake reliability testing as part of their training. Analysis of variance demonstrated no statistically significant differences within or between observers (Cameron, 1984; Carter et al., 1994). A Martin anthropometer was used to measure height to the last 0.1cm, a Schoenle electronic scale to measure weight to the last complete 0.1kg, a steel tape for circumference measurements to 0.1cm, a spreading calliper for breadth measurements to the last 0.1cm and Harpenden (John Bull) skinfold calliper with inter-jaw pressure of 10g/mm^2 to the last 0.2mm. The body mass index (BMI) (kg/m^2) was also calculated.

Analysis

Data were analysed using standard descriptive statistics of central tendency and variability to determine growth patterns for height, weight and BMI for boys and girls. Measures of height-for-age, weight-for-age, and weight-for-height were also expressed as Z-scores of the NCHS (Hammill et al., 1979) or NHANES I and II samples (Frisancho, 1990). Z-score values of less than –2 for height-for-age and weight-for-height were used to determine the prevalence of stunting and wasting respectively (Gibson, 1990). Independent t-tests were applied within and between samples to test the significance of differences between sexes and between the Ellisras sample and the NHANES or NCHS reference data.

It is important to note that both weight-for-age and height-for-age Z-score were based on the NHANES reference values. Z-score values of weight-for-height were based upon NCHS data (Hammill et al., 1979), which does not include such data beyond 10.0 years of age in girls. Hence no mean Z-score values of weight-for-height could be determined for those female subjects in the Ellisras sample older than 10.0 years.

RESULTS

Tables 1 and 2 exhibit the means and standard deviations (SD) for height, weight, BMI, and Z-score values of weight-for-age (WAZ), height-for-age (HAZ) and weight-for-height (WHZ) for Ellisras rural boys and girls age 3 to 10 years.

Table 1: Mean and Standard deviation (SD) for weight, height, body mass index (BMI) and the Z-score values of weight-for-age (WAZ), height-for-age (HAZ) and weight-for-height (WHZ) of Ellisras boys

Age (years)	Mean Age (years)	N	Weight (kg)	Height (cm)	BMI ($kg.m^{-2}$)	WAZ	HAZ	WHZ
3.0-3.9	3.7	22	12.8 (2.0)	99.1 (6.4)	12.9 (1.3)	-1.4 (1.0)	-0.0 (1.4)	-2.1 (1.0)
4.0-4.9	4.6	67	14.6 (1.9)	104.9** (4.7)	13.5 (1.5)	-1.1 (0.8)	-0.4 (0.9)	-1.6 (1.1)
5.0-5.9	5.5	81	16.6 (2.2)	111.0** (5.3)	13.4 (1.2)	-1.2 (0.7)	-0.2 (1.0)	-1.5 (0.9)
6.0-6.9	6.6	143	18.0 (2.5)	117.2* (5.8)	13.1 (1.3)	-1.3 (0.7)	-0.4 (1.1)	-1.8 (1.0)
7.0-7.9	7.5	199	19.7* (2.8)	121.7*** (6.3)	13.3* (1.3)	-1.3 (0.7)	-0.5 (1.1)	-1.7 (1.3)
8.0-8.9	8.4	111	21.2* (3.3)	125.3 (5.8)	13.4* (1.4)	-1.3 (0.6)	-0.7 (0.9)	-1.7 (1.0)
9.0-9.9	9.4	47	23.0 (3.7)	127.9 (6.2)	13.9 (1.3)	-1.3 (0.6)	-1.4 (1.1)	-1.4 (0.9)
10.0-10.9	10.4	14	22.3 (3.9)	128.8 (6.7)	13.4 (1.6)	-1.7 (0.5)	-1.7 (1.0)	-1.9 (1.1)

* = $p<0.05$ ** = $p<0.01$ *** = $p<0.001$

Table 2: Mean and Standard deviation (SD) for weight, height, body mass index (BMI) and the Z-score values of weight-for-age (WAZ), height-for-age (HAZ) and weight-for-height (WHZ) of Ellisras girls

Age (years)	Mean Age (years)	N	Weight (kg)	Height (cm)	BMI ($kg.m^{-2}$)	WAZ	HAZ	WHZ
3.0-3.9	3.5	25	12.5	96.4	13.3	-1.2	-0.3	-1.6
			(2.3)	(5.6)	(1.8)	(1.0)	(1.2)	(1.3)
4.0-4.9	4.5	70	14.6	103.9**	13.4	-1.1	-0.2	-1.1
			(2.9)	(8.3)	(1.5)	(1.2)	(1.7)	(2.2)
5.0-5.9	5.6	80	16.1	110.6**	13.1	-1.1	-0.3	-1.5
			(2.0)	(5.4)	(1.4)	(0.6)	(1.0)	(1.0)
6.0-6.9	6.5	173	17.6	116.6*	12.9	-1.2	-0.3	-1.7
			(2.7)	(5.1)	(1.5)	(0.7)	(0.9)	(1.2)
7.0-7.9	7.5	171	19.1*	121.2***	12.9*	-1.3	-0.5	-1.8
			(2.9)	(4.9)	(1.5)	(0.7)	(0.8)	(1.1)
8.0-8.9	8.4	87	20.2*	124.5	13.0*	-1.3	-0.8	-1.7
			(3.3)	(6.4)	(1.4)	(0.5)	(1.1)	(1.6)
9.0-9.9	9.4	28	22.0	127.3	13.5	-1.4	-1.1	-0.7
			(3.3)	(7.2)	(1.3)	(0.5)	(1.0)	(3.1)
10.0-10.9	10.4	17	21.8	128.6	13.1	-1.6	-1.7	---
			(5.1)	(7.8)	(2.4)	(0.6)	(1.1)	---

* = p<0.05 ** = p<0.01 *** = p<0.001

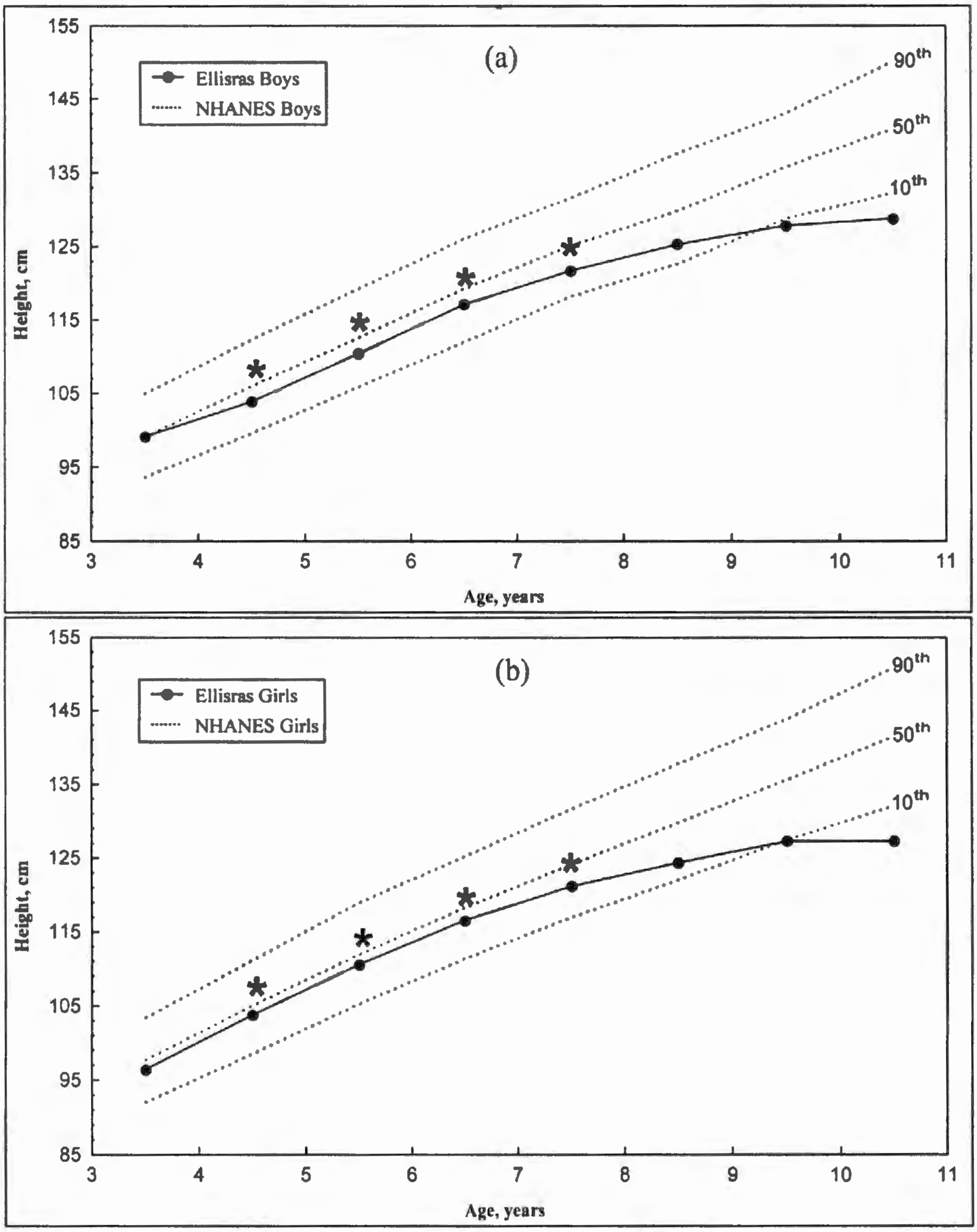


Fig. 1: Mean heights of the Ellisras sample compared to the 10th, 50th, 90th centiles of the NHANES III reference data (a) boys, (b) girls

Height

Height tends to follow a pattern between 3 to 7 years, which runs parallel to the 50th centile and within the range of 0.0 to – 0.5 Z-scores. After 7 years of age there is a consistent tendency for the mean height to fall away from the 50th centile, thus by 10 years of age mean values for boys and girls are less than the 10th centile for the NHANES reference (-1.5 to -2.0 Z-scores). The differences between sexes were significant between 4.0 and 8.0 years.

Weight

Mean weight follows a more consistent pattern from 3 to 10 years of age. The values are on or just beneath the 10th centile with Z-scores between -1 and -1.5. Although the mean weight of boys and girls show a significant difference from 7.5 to 8.5 years, the lack of significant difference between the sexes for the majority of mean weight values in comparison to mean height values may indicate that the weights of the Ellisras boys are being differentially affected by environmental (i.e. nutritional) stresses compared to the girls. If height and weight in both sexes were being equally affected, then significantly lower heights in females will be expected to be accompanied by significantly lower weight. The fact that we do not see simultaneous significant differences in height and weight between the sexes implies that weight in boys is being affected more than height (Fig. 2).

Weight-for-height

Weight-for-height Z-scores varies between –1 and –2 throughout the age range indicating a significant amount of wasting in this sample. Once again, the males appeared to be differentially affected, with generally lower weight-for-height z-scores by age (fig. 3).

Body Mass Index

Both sexes demonstrate BMI values lower than the NHANES 5th centile throughout the age range once again confirming the significant amount of wasting in this sample (fig. 4).

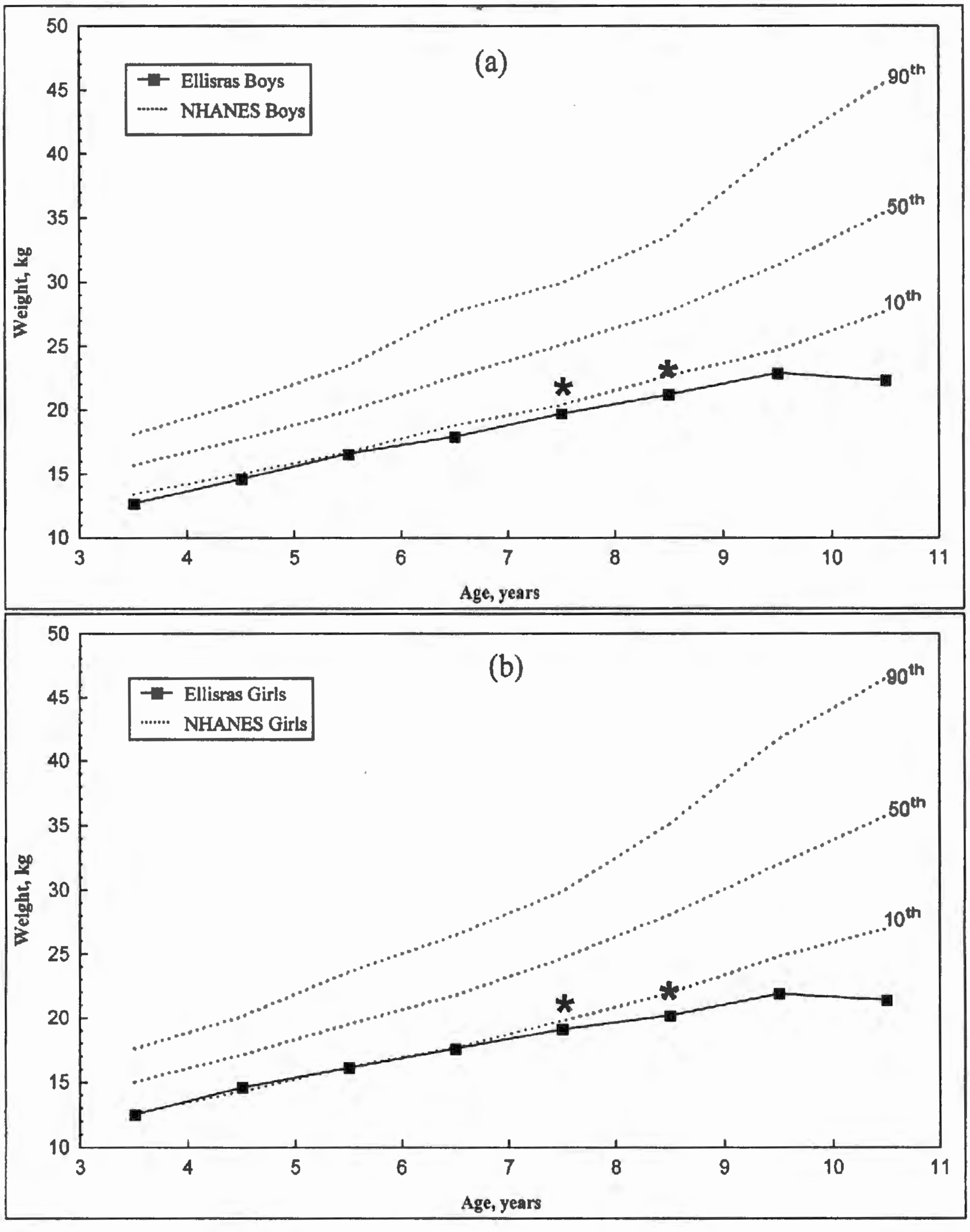
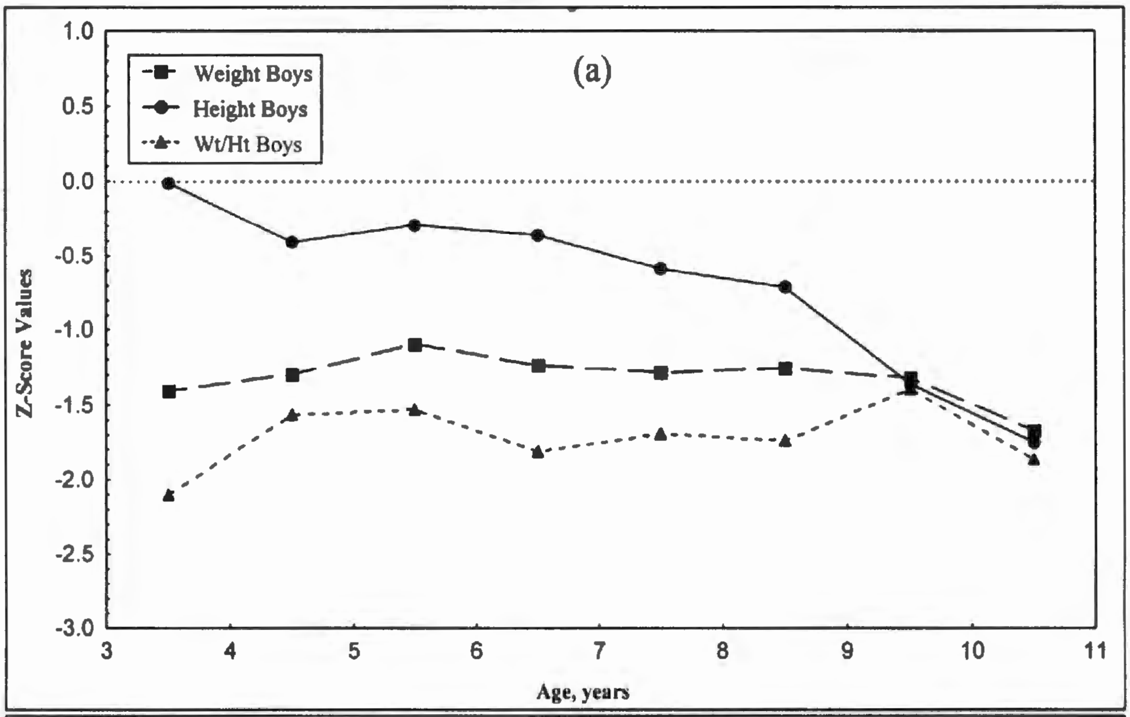


Fig. 2: Mean weights of the Ellisras sample compared to the 10th, 50th, 90th centiles of the NHANES III reference data (a) boys, (b) girls



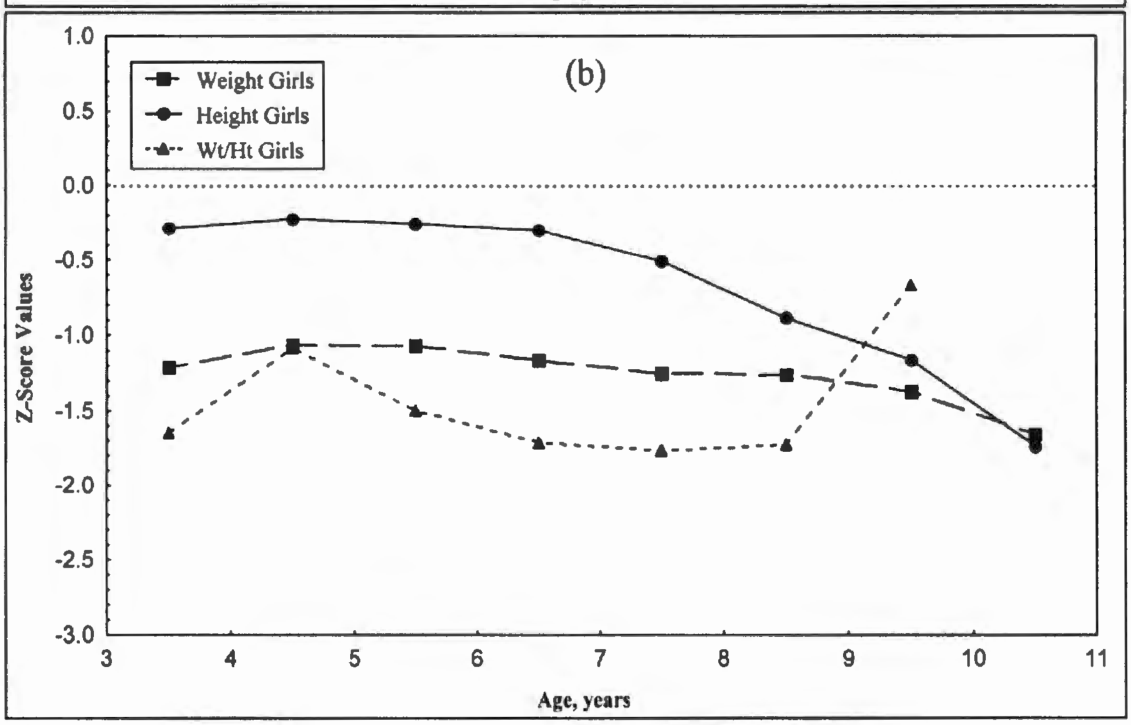


Fig 3: Mean Z-score values of height, weight and weight-for-height (Wt/Ht) for the Ellisras sample (a) boys, (b) girls

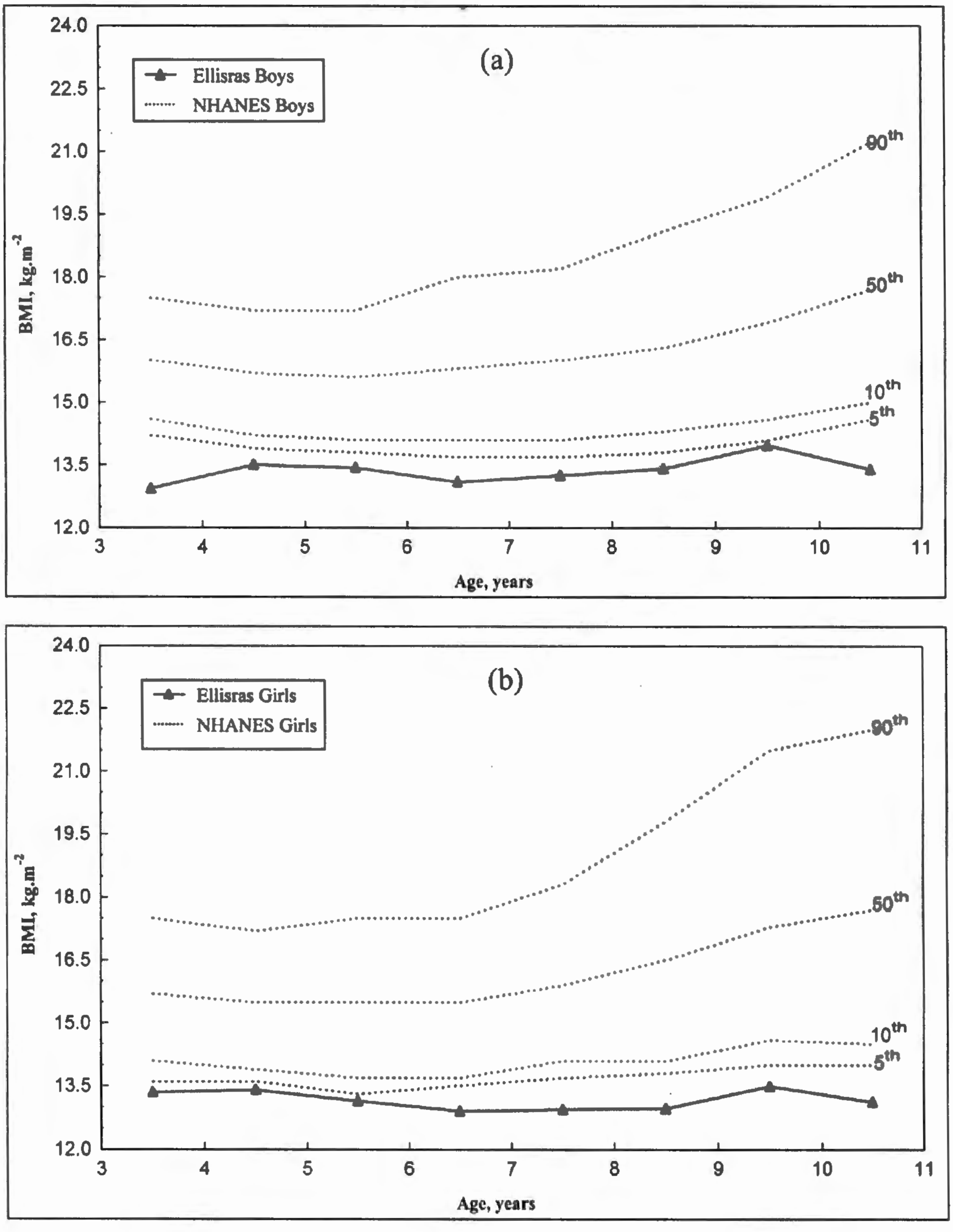


Fig. 4: Mean body mass index (BMI) of the Ellisras sample compared to the 5th, 10th, 50th, 90th centiles of the NHANES III reference data (a) boys, (b) girls

Stunting (HAZ < -2), wasting and low weight-for-age

Table 3: Percentage prevalence as determined by a Z-score value of less than –2 for weight-for-age (WAZ), height-forage (HAZ) and weight-for-height (WHZ) of Ellisras boys

Age (years)	Mean Age (years)	N	WAZ (%)	HAZ (%)	WHZ (%)
3.0-3.9	3.7	22	36.4	4.6	54.6
4.0-4.9	4.6	67	20.9	6.0	28.4
5.0-5.9	5.5	81	22.2	3.7	25.9
6.0-6.9	6.6	143	42.7	7.7	39.2
7.0-7.9	7.5	199	28.6	5.5	36.2
8.0-8.9	8.4	111	26.1	12.6	42.3
9.0-9.9	9.4	47	44.7	12.8	27.7
10.0-10.9	10.4	14	64.3	28.6	42.9

Table 4: Percentage prevalence as determined by a Z-score value of less than –2 for weight-for-age (WAZ), height-forage (HAZ) and weight-for-height (WHZ) of Ellisras girls

Age (years)	Mean Age	N	WAZ (%)	HAZ (%)	WHZ (%)
3.0-3.9	3.5	25	44.0	8.0	40.0
4.0-4.9	4.5	17	24.1	10.0	25.7
5.0-5.9	5.6	80	10.0	5.0	26.3
6.0-6.9	6.5	173	29.5	4.1	44.5
7.0-7.9	7.5	171	32.2	3.5	35.7
8.0-8.9	8.4	87	29.9	5.8	44.8
9.0-9.9	9.4	28	39.3	21.4	21.4
10.0-10.9	10.4	17	64.7	41.8	---

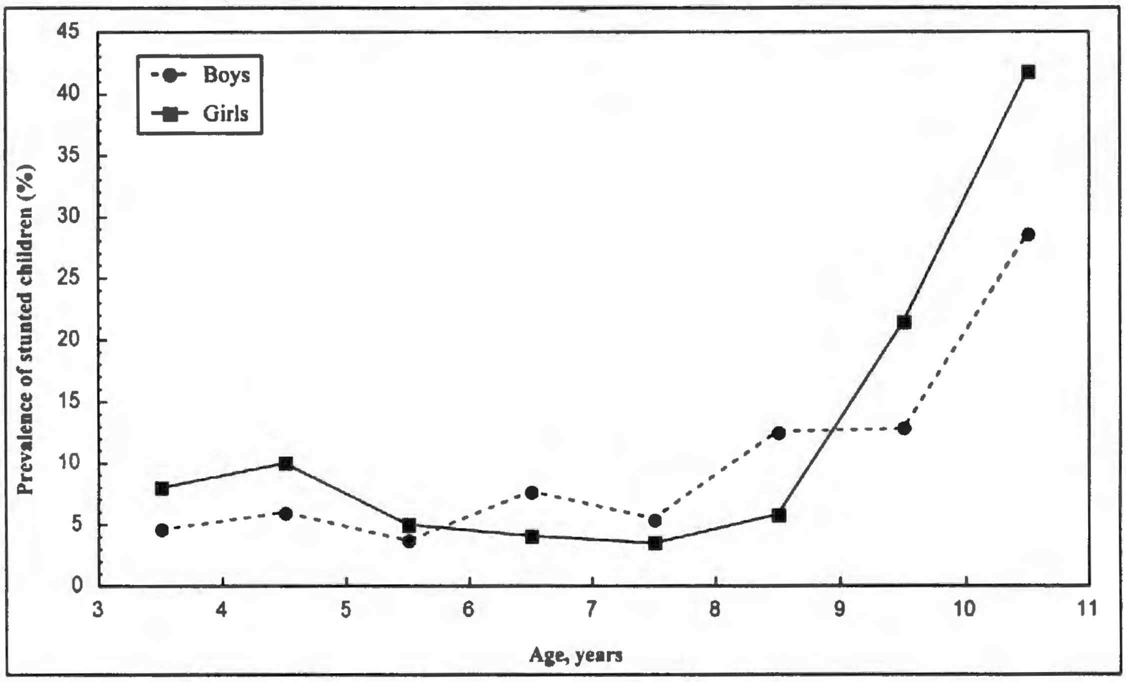


Fig. 5: Percentage prevalence of stunted Ellisras children

The prevalence of stunting, height for age z-scores < -2 follows a similar patterns in boys and girls until 8 years of age, at which time the prevalence in girls increases to become almost twice that of boys through 10 years of age. This relatively dramatic increase in prevalence from 8 years of age coincides with the fall of mean height values from the 50th centile as the children approach the adolescence growth spurt (fig. 5).

DISCUSSIONS

This study sought to describe the growth and nutrition status of children living in a rural community in South Africa. Whilst this study is designed as a mixed-longitudinal study, this paper reports the initial cross sectional analysis following the first period of data collection in December 1996. Patterns of growth in height suggest that these children grow parallel to the 50th centile up to age six, and then both sexes demonstrate a gradual decline in height velocity such that their mean heights diverge by approximately 0.5 cm per year. However, an analysis of changes in mean values indicate that the effects of stress may be a gradually accumulating process and that the growth increments become increasingly poor in contrast to those of the reference samples.

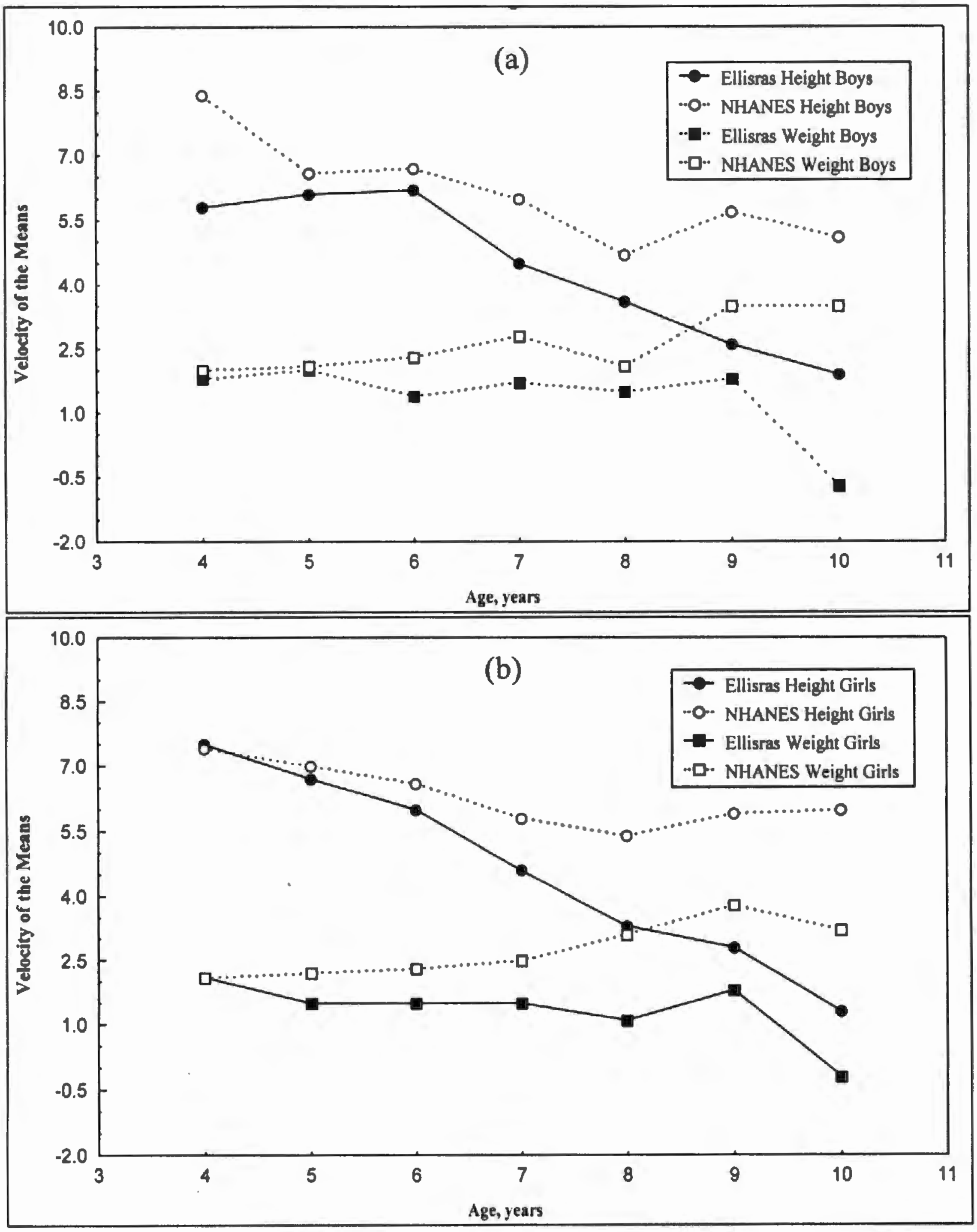


Fig. 6: Velocity of the means for height and weight of the Ellisras sample compared to the NHANES III reference data (a) boys, (b) girls

Figure 6 illustrates the increments of the mean values ("velocity of the means") for height and weight in boys and girls. In both sexes weight increments are consistently between 1 and 2kg per year in contrast to the increments of the reference sample, which gradually increase to approximately 3kg per year by 10 years of age. The result of the lack of increase in weight increments by age in the Ellisras sample is that the mean values diverge from the 10^{th} centile of the reference (Fig. 2). Two factors are interesting in this pattern of weight gain; firstly, the absence of increased increments and secondly, the consistent nature of increment up to 10 years of age i.e. there appears to be no age during which children would appear to be more sensitive to their nutritional environment. Conversely, increments of height means reflect different patterns in boys and girls prior to 7 years of age. Whereas girls appear to maintain a consistent decline in height velocity from 4 - 6 years of age, boys demonstrate a slightly increasing velocity prior to six years of age and then velocities similar to the girls. The net result of these reducing increments is that the height status of the Ellisras children becomes progressively compromised (Fig. 1).

The longitudinal data are not yet available to allow an assessment of whether these reducing increments result in permanent stunting. It is not known whether the change in increment of mean height for boys around 6 years of age is related to some change in nutritional practice. Although no empirical data are available on nutritional intake and food practices in these villages, one of the current authors (KDM) lived in this area throughout childhood and reports that nutritional practices amongst these rural families are closely linked to the age of the child. Infants and young children would spend their time in and around the house and would be likely to obtain food when it is being prepared by the mother, grandmother or older female siblings. The capability of boys to become independent goat and cattle herders coincides with their attendance at school. They will return from school each afternoon to carry out their animal chores and it is at this time that nutritional intake is likely to deteriorate because they are distanced from the source of preparation and food is unlikely to be kept for their return. These boys, usually aged about nine to ten years, rely on gathering vegetable foods (berries, etc), trapping rabbits and hares, and/or killing birds which are then cooked and eaten during the day. They therefore do not have a guaranteed daily nutritional intake. Girls are not involved in animal husbandry and stay around the home to help with food preparation. It would therefore appear that boys are more at risk of malnutrition in terms of both quality and quantity of food. The staple family diet is porridge (mealie-meal) which is prepared daily in the most families by female siblings or parents. This porridge is left in the cooking pot for members of the family to serve themselves when they are hungry. Younger children (less than 7 years of age) are supplied with food after preparation but older children are required to serve themselves and may, therefore, be subject to reduced intake as a result of competition for this finite source. In common with the data on Pedi children reported by Steyn et al. (1992) it may be that these mainly Tswana children have two meals a day with very low energy intake. While the above description is anecdotal and may be viewed as having little scientific basis, such reports of dietary behaviour are rare in the literature on children in Southern Africa and, therefore, should not be ignored as a possible explanation of differing nutritional intake.

Only one other published study relates to this growth of children from this area of southern Africa. Cameron (1992) reported on the growth of Tswana children from Vaalwater, some 50km from the present study site near Ellisras. The Vaalwater children were the sons and daughters of farm laborers and enjoyed the relatively protected nutritional environment provided by the farm owner, who was a practicing pediatrician. In common with the present study the Vaalwater children demonstrated low ratios of weight-for-height but in contrast to the present study they were consistently above the NCHS 10^{th} centile. Therefore it would appear that low weight-for-height is a characteristic of children in this area. However, the greater instability of nutritional environment experienced by the Ellisras children is emphasized by their precariously low nutritional status.

The net result of the poor nutritional environment in which these Ellisras children live is an increasing prevalence of stunting, and mean heights, weights, and BMI's that are less than the reference 5^{th} centile by 10 years of age. It may be that the progressively reduced increments during this period of growth reflect an adaptive mechanism and that "compensatory" adolescent growth may result in adult heights that are closer to the 50th centile (Cameron et al., 1994). However, there is little evidence to suggest that, in the boys at least, mean weights will recover because low BMI's are characteristic of African adult males (Eveleth and Tanner, 1991). Martorell et al. (1992) reported a loss of functional ability (physical work capacity) in young Gautemalan adults who had become stunted by the age of three. It would appear that stunting in the current sample becomes most marked towards the end of childhood and there is no empirical evidence to suggest that this may be permanent. However, the implication that the long-term consequence of stunting in childhood is a loss of physical work capacity is of real concern and prompts further investigation of the causes of poor growth amongst these rural children.

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Substance farming in Ellisras rural area

4

PHYSICAL GROWTH AND SOCIO-ECONOMIC STATUS OF SOUTH AFRICAN RURAL CHILDREN AGED 3 TO 10 YEARS

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ABSTRACT

Purpose. The purpose of this study is to investigate the prevalence of stunting and wasting of a cross-sectional sample of Ellisras rural children aged 3 to 10 years in relation to their socio-economic background. Data were obtained from the first year of the Ellisras longitudinal study.

Methods. Health status and socio-economic status of 1339 children (687 boys and 652 girls) ranging from 3 to 10 years were determined using standard anthropometric techniques and socio-economic status groupings. Measurements of weight-for-age (WAZ), height-for-age (HAZ) and weight-for-height (WHZ) were expressed as z-score values of the NHANES III sample for the high, moderate and low socio-economic status. A Z score of less than -2SD was used as the cut off point to determine the prevalence of stunting and wasting.

Results. Mean WAZ scores were low throughout the different socio-economic groups. The prevalence of stunting and wasting in all three socio-economic groups was high. There was a high level of stunting (19.9% to 51.0%) and wasting (22.8% to 39.9%) in all three socio-economic groups. There is an ongoing social dilution of higher and lower social classes in the rural community, but with a considerable selectivity in the process.

Conclusion. In this study we found no difference in growth between children of different social groups. Variation in height and weight of girls was mainly affected by the biological factors. Therefore further investigation of the cause of poor growth among these rural children is imperative.

Key words: Anthropometry, growth, nutritional status, socio-economic status, sex differences, South African rural children.

INTRODUCTION

An assessment of the intensity with which various socio-economic factors influence human growth, producing variation between individuals growth, is of primary importance in growth and family income are well documented in the Northern Hemisphere (Tanner, 1962; Rona & Chinn, 1987; Bogin, Wall & MacVean, 1990; Task et al., 1991). In South Africa, urban black schoolchildren from families in a high socio-economic bracket were reported to be well nourished compared to those with lower socio-economic backgrounds (Walker & Walker, 1977). Recently, studies on the overall physical growth changes of rural children of South Africa have also been reported (Cameron, 1991; Monyeki, Pienaar & De Ridder, 1995; Monyeki & Toriola, 1997; Kekana & Monyeki, 1998). In all the South African studies it was clearly depicted that rural children were consistently shorter than urban children were. However these studies did not identify the specific role played by individual factors on the growth of the children.

In 1996 a longitudinal study was initiated in a rural community of South Africa in order to examine physical growth patterns, nutritional status and socio-economic background of rural children. The purpose of this report is to investigate prevalence of stunting and wasting in a cross-sectional sample of Ellisras rural children aged 3 to 10 years in relation to their socio-economic background.

MATERIAL AND METHODS

Geographical location

This study was carried out in Ellisras villages situated in the northwestern area of the Northern Province of South Africa. These villages, approximately 70 km from the provincial town of Ellisras (23^0 40S 27^0 44W), are adjacent to the Botswana border. The Iscor coal mine and Matimba electricity power station are the major sources of employment for many of the Ellisras rural residents, whereas the remaining workforce is involved in subsistence farming and cattle rearing, and a minority in teaching and the civil service.

Sampling

The study was undertaken at 22 schools (10 pre-school and 12 primary schools) randomly selected from a total of 68 schools within the Ellisras area. A total of 687 boys (173 pre-school boys and 514 primary school boys) and 652 (177 pre-school girls and 475 primary school girls) who were measured in the first visit (Nov 1996) were included in the analysis. The subjects birth records were obtained from the Principals of each school. Only those birth records that had been verified against health clinic records were used to determine the age of each participant. Each of the 22 chosen schools were assigned to one of the calendar age group (3-10 years) and only children whose verified age was within the category for a particular school were assessed.

Anthropometry

Height and weight were measured according to the standard procedures described by the International Society for the Advancement of Kinanthropometry (ISAK). A Martin anthropometer was used to measure height to the last complete 0.1 cm and a Schoenle electronic scale to measure weight to the last complete 0.1 kg. The survey was carried out over a three-week period by 16 anthropometrists, who were required to undertake reliability testing as part of their training. Analysis of variance demonstrated no statistically significant differences within or between observers (Carter et al., 1994; De Ridder, 1993).

Socio-economic status

Information about the father`s and mother`s occupation was recorded by trained personnel who interviewed the parents of the children that took part in the study. The bread winner`s occupation was used to describe the socio-economic status of the child, which was coded according to Lindgren and Cernerud (1992) and adapted for use in the Northern Province. The Ellisras rural community children were classified according to the following socio-economic groups (see Table 1):

GROUP I Professionals, high ranking civil servants and executives businessmen executives, tradesmen (e.g. electricians)

GROUP II Clerical works, salesmen, traditional healers, makers of handicrafts

GROUP III Labourers, cleaners, house helpers, shop assistants, drivers, vendors, subsistence farmers

Table 1: Ellisras rural sample size by age, sex and socio-economic status

Age	**Group I (high income)**		**Group II (moderate)**		**Group III (low income)**	
	Males	Females	Males	Females	Males	Females
3	4	4	5	3	15	19
4	13	12	16	13	39	45
5	10	16	19	14	52	51
6	27	26	35	38	83	111
7	34	32	58	53	108	83
8	19	15	39	30	51	42
9	4	4	8	6	34	17
10	-	-	5	5	9	13
Total	**111**	**109**	**185**	**162**	**391**	**381**

Analysis

Nutritional indicators namely: height-for-age (HAZ) and weight-for-age (WAZ) and weight-for-height (WHZ) values were based on the NHANES III reference sample (Frisancho, 1990). Z-score values of less than –2 SD for HAZ, WHZ and WAZ were used to determine the prevalence of stunting and wasting (Cameron et al., 1998). Standard descriptive statistics for height, weight, HAZ, WAZ, and WHZ were determined. Independent t-tests were applied to test for significant differences between sexes. Significant differences ($p<0.05$) among the means of the socio-economic groups in each age group was determined by analysis of variance (ANOVA) and the Newman-Keuls post-hoc test.

RESULTS

Tables 2 and 3 contain the mean (±SD) values for height, weight, height-for-age (HAZ), weight-for-age (WAZ) and weight-for-height (WHZ) z-scores by age, gender and the different socio-economic groups. Table 4 presents the prevalence of stunting and wasting within each socio-economic group.

In group I the boys were taller than the girls across the age. Differences in weight varied between the sexes with no specific trend. In Group II no specific trends were noticed in height or weight between the sexes. Boys in group III males were generally taller than girls.

The same trends in HAZ, WAZ and WHZ were noted for all three groups. HAZ values were generally lower in the younger age group and high (poor) in the older children of both sexes. This trend was reversed in WAZ and WHZ z-scores.

Height

Ellisras boys of socio-economic group I were taller than girls at virtually all the ages by 0.9 to 7.3 cm from the ages of 3 to 9 years (Table 2). This has statistical difference ($p<0.05$) at the ages of 3, 7 and 9 years. However, Ellisras girls in socio-economic group II were slightly taller than boys at the ages of 4, 5, 7 and 10 years by 1.1 to 5 cm, while boys were taller than girls at the ages of 3, 6, 8 and 9 years which reach statistical difference ($p<0.05$) at the ages of 4 and 10 years for girls and at the ages of 3 and 8 years for boys (Table 2). A small growth difference of 0.3 cm to 3.4 cm was found in socio-economic group III which was significant ($p<0.05$) at the ages of 4, 9 and 10 years. Boys were slightly taller than girls in this socio-economic group.

Weight

Almost similar growth patterns was found between boys and girls in socio-economic group I and II with boys significantly ($p<0.05$) heavier than girls at the ages of 3, 4, and 9 years for socio-economic group I, and 3 and 8 years for socio-economic group II. The small growth difference of 0.2 kg to 5.6 kg between the ages of 3 to 9 years of socio-economic group I and 0.3 kg to 2.6 kg for socio-economic group II was observed (Table 2).

Table 2: Descriptive statistics (mean +SD) of height (Ht) and weight (WT) for Ellisras rural children in three socio-economic groups

AGE	GROUP I (HIGH INCOME)				GROUP II (MODERATE)				GROUP III (LOW INCOME)			
	HT		WT		HT		WT			HT		WT
	M	F	M	F	M	F	M	F	M	F	M	F
3	102.5*	97.2*	13.3*	11.8*	98.9*	91.7*	13.2*	10.6*	97.3	97.3	12.1	12.9
	(6.51)	(5.52)	(2.18)	(1.93)	(7.38)	(3.72)	(2.57)	(0.35)	(6.19)	(5.83)	(1.92)	(2.33)
4	103.2	102.3	13.8*	14.0*	104.1*	109.3*	14.3*	16.2*	104.1*	102.7*	15.0	14.2
	(3.74)	(5.28)	(2.16)	(3.06)	(5.39)	(14.0)	(2.05)	(4.39)	(4.63)	(5.98)	(1.57)	(2.19)
5	112.6	111.7	16.6	16.1	111.3	112.4	16.4	17.2	109.8	109.9	16.7	15.7
	(8.99)	(4.53)	(3.97)	(1.47)	(3.72)	(4.52)	(1.35)	(2.39)	(8.58)	(5.97)	(2.10)	(1.91)
6	118.3	117.3	18.7	17.7	117.6	117.1	17.9	17.3	116.6	116.3	17.8	17.6
	(5.83)	(4.49)	(2.76)	(2.72)	(6.13)	(4.69)	(2.49)	(2.37)	(6.29)	(5.39)	(2.40)	(2.76)
7	123.0*	120.8*	18.3	18.6	120.5	121.0	19.1	18.5	121.9	121.4	19.8	19.4
	(6.37)	(4.52)	(2.80)	(2.55)	(5.40)	(5.01)	(2.87)	(3.16)	(6.70)	(5.08)	(2.80)	(2.97)
8	124.1	123.9	20.9	20.4	125.3*	123.4*	21.1*	19.0*	125.7	126.5	21.2	21.4
	(7.21)	(8.29)	(1.93)	(3.22)	(6.10)	(6.38)	(3.36)	(3.20)	(5.23)	(6.94)	(3.04)	(3.47)
9	129.6*	122.3*	24.6*	19.0*	125.9	125.9	21.9	21.3	128.2*	126.2*	23.1	21.6
	(8.45)	(5.99)	(4.35)	(3.21)	(5.14)	(4.03)	(3.09)	(2.88)	(6.36)	(5.51)	(3.79)	(2.97)
10	-	-	-	-	124.7*	126.8*	22.6	21.1	131.0*	127.6*	22.1	21.5
					(8.10)	(13.78)	(5.50)	(1.47)	(4.97)	(7.82)	(1.25)	(1.23)

* Student t-tests between sexes, P<0.05

Table 3: Descriptive statistics (mean + SD) of height-for-age, weight-for age and weight-for-height z-scores for Ellisras rural children in three socio-economic groups

	GROUP I (HIGH INCOME)						GROUP II (MODERATE)						GROUP III (LOW INCOME)					
AGE	HAZ		WAZ		WHZ		HAZ		WAZ		WHZ		HAZ		WAZ		WHZ	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
3	0.7	-0.3	-1.2	-1.5	-2.4	-2.1	-0.4	-1.3	-1.2	-2.1	-1.9	-2.1	-0.4	-0.1	-1.6	-1.0	-2.3	-1.5
	(1.38)	(0.72)	(1.03)	(0.92)	(1.24)	(1.20)	(1.560	(0.83)	(1.22)	(0.17)	(0.96)	(1.03)	(1.32)	(1.29)	(0.85)	(1.11)	(0.84)	(1.35)
4	0.5	-0.5	-1.6	-1.3	-2.1	-1.6	-0.4	0.9	-1.4	-0.4	-1.9	-1.5	-0.4	-0.5	-1.1	-1.2	-1.4	-1.5
	(0.73)	(1.08)	(0.89)	(1.27)	(1.37)	(1.48)	(1.06)	(2.86)	(0.85)	(1.83)	(1.28)	(0.82)	(0.90)	(1.22)	(0.65)	(0.92)	(0.95)	(1.06)
5	1.0	-0.1	-1.1	-1.1	-1.7	-1.5	-0.3	-0.1	-1.2	-0.7	-1.6	-1.1	-0.5	-0.4	-1.1	-1.2	-0.9	-1.5
	(1.70)	(0.83)	(1.32)	(0.45)	(1.02)	(0.71)	(0.70)	(0.83)	(0.45)	(0.74)	(0.74)	(0.77)	(1.61)	(1.11)	(0.70)	(0.59)	(0.21)	(0.84)
6	-0.2	-0.2	-1.1	-1.1	-1.3	-1.6	-0.3	-0.2	-1.2	-1.2	-1.5	-1.7	-0.5	-0.4	-1.3	-1.1	-1.4	-1.5
	(1.07)	(0.80)	(0.74)	(0.76)	(0.56)	(1.01)	(1.13)	(0.83)	(0.67)	(0.66)	(0.88)	(0.88)	(1.61)	(0.96)	(0.65)	(0.77)	(0.61)	(0.89)
7	-0.4	-0.6	-1.2	-1.3	-1.5	-1.6	-0.8	-0.5	-1.4	-1.3	-1.6	-1.6	-0.6	-0.5	-1.2	-1.2	-1.5	-1.5
	(1.12)	(0.75)	(0.67)	(0.56)	(0.82)	(0.74)	(0.95)	0.83	(0.68)	(0.70)	(0.74)	(0.84)	(1.17)	(0.84)	(0.66)	(0.66)	(0.71)	(0.82)
8	-0.9	-1.0	-1.3	-1.2	-1.3	-1.2	-0.7	-1.1	-1.3	-1.4	-1.3	-1.5	-0.7	-1.0	-1.2	-1.3	-1.3	-1.3
	(1.13)	(1.38)	(0.74)	(0.66)	(0.59)	(0.66)	(0.96)	(1.06)	(0.64)	(0.51)	(0.67)	(0.45)	(0.82)	(1.09)	(0.58)	(0.49)	(0.65)	(0.45)
9	-1.1	-1.3	-1.1	-1.4	-1.0	-1.4	-1.7	-0.6	-1.5	-1.1	-1.3	-1.2	-1.3	-0.6	-1.3	-1.0	-1.2	-1.1
	(1.46)	(0.99)	(0.69)	(0.51)	(0.27)	(0.51)	(0.88)	(0.67)	(0.49)	(0.46)	(0.45)	(0.48)	(1.09)	(0.91)	(0.60)	(0.47)	(0.61)	(0.46)
10	-	-	-	-	-	-	-2.3	-2.0	-1.6	-1.7	-1.2	-1.5	-1.2	-1.9	-1.7	-1.7	-1.7	-1.5
							(1.18)	(1.86)	(0.71)	(0.64)	(0.66)	(0.47)	(0.82)	(1.06)	(0.39)	(0.63)	(0.45)	(0.84)

Table 4: Prevalence of stunting and wasting for Ellisras rural children aged 3 to 10 years in three socio economic groups

AGE	GROUP I (HIGH INCOME)						GROUP II (MODERATE)						GROUP III (LOW INCOME)					
	HAZ %prevalence < -2		WAZ %prevalence < -2		WHZ %prevalence < -2		HAZ %prevalence < -2		WAZ %prevalence < -2		WHZ %prevalence < -2		HAZ %prevalence < -2		WAZ %prevalence < -2		WHZ %prevalence < -2	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
3	0.0	0.0	0.0	0.0	0.0	0.0	20.0	66.0	4.0	66.0	10.0	16.0	13.0	21.1	60.0	31.6	23.0	33.0
4	23.0	25.0	46.2	41.7	19.2	41.0	6.3	7.7	31.3	15.3	13.8	26.1	2.5	15.6	20.5	31.0	26.0	28.9
5	20.0	6.3	30.3	6.3	10.0	11.8	0.0	0.0	26.3	7.1	17.9	12.0	38.0	28.0	34.0	15.6	34.6	43.1
6	22.2	50.0	37.0	50.0	14.4	14.0	17.1	2.6	42.8	50.0	10.0	17.8	16.9	9.0	48.2	4.5	24.5	26.8
7	17.6	37.5	26.4	37.0	14.0	10.0	24.1	9.4	37.0	39.6	14.0	10.9	16.7	10.8	26.9	31.0	28.5	23.4
8	31.6	26.7	31.0	26.7	12.0	10.0	20.5	36.7	23.1	36.6	13.0	13.0	17.6	33.0	19.6	28.5	29.0	33.3
9	25.0	50.0	25.0	50.0	0.0	5.0	22.5	0.0	50.0	0.0	10.0	13.0	20.0	11.7	44.0	11.7	29.0	5.9
10	-	-	-	-	-	-	60.0	60.0	60.0	80.0	10.0	10.0	11.1	61.2	66.0	61.5	26.7	26.2
Mean:	**19.9**	**27.9**	**28.0**	**37.4**	**8.7**	**11.5**	**51.0**	**26.3**	**22.8**	**34.3**	**36.9**	**46.1**	**17.0**	**18.7**	**32.6**	**39.9**	**27.7**	**27.6**
(SD)	**(9.30)**	**(19.67)**	**(14.27)**	**(16.21)**	**(1.21)**	**(2.70)**	**(19.30)**	**(23.0)**	**(27.51)**	**(17.33)**	**(14.27)**	**(16.21)**	**(2.7)**	**(1.3)**	**(23.00)**	**(27.51)**	**(17.33)**	**(28.28)**

Weight-for Age (WAZ), Height-for-Age (HAZ) and Weight-for-height (WHZ) scores

Mean WAZ scores were low throughout the different socio-economic groups. It decreased from -1.6 to -1.1 in socio-economic group I, -1.6 to -0.4 in socio-economic group II and -1.6 to -1.0 in socio-economic group III for both boys and girls aged 3 to 10 years. These reductions in WAZ scores increases the prevalence of wasting from 22.8% to 39.9% (Table 4) for the three different socio-economic groups from the age of 3 to 10 years.

DISCUSSIONS

In this study, cross-sectional results of anthropometric measurements carried out in rural Ellisras children of South Africa are presented with particular emphasis on the effect of the socio-economic background on physical growth. The prevalence of stunting and wasting in all three socio-economic groups was high.

Table 1 shows the classification of Ellisras rural children according to parental occupation. Few of the Ellisras sample fell in Group I and Group II at the age of 3 to 5 years while no children could be classified at the age of 10 years for socio-economic Group I. This might be the result of a limited sample in each age group since children initially not selected according to the parental occupation but were randomly selected according to their age group.

Although socio-economic status of the family is widely used in growth studies, it remains a controversial topic. Among social factors, fathers` occupational status is the most frequently used to denote socio-economic level of the family in analysing the height and weight of children (Lindgren & Cernerud, 1992). In developing countries, Cameron (1991) and Walker and Walker (1977) validated the use of both parents` occupational status to describe the social level of the family, which has been the case in this study.

The most striking finding of this study is the high level of stunting (19.9% to 51.0%) and wasting (22.8% to 39.9%) in all three socio-economic groups. A possible reason for this is the fact that many children in developing countries became stunted during infancy as a result of inappropriate weaning practices, repeated infections and poor diet- all in the context of poverty (Adair & Guilkey, 1996; Wang et al., 1994). There is an ongoing social dilution of higher and lower social classes in the rural community, but with considerable selectivity in the process. Children from the higher socio-economic group in the urban areas of South Africa have weight and height values which until puberty resemble those of Whites (Walker, 1966; Cameron, 1991; Lindgren & Cernerud, 1991). This social mobility causes a dilution over time in the distribution of socio-economic groups. Some groups increase in size while others decrease (Lindgren & Cernerud, 1992). This may lead to a successive selection of a socially advantaged or disadvantaged person in a specific socio-economic group.

In this study we found no difference in growth between children of different social groups. Variation in height and weight of girls was mainly affected by the biological factors which Eveleth and Tanner (1991) explained as differences in growth tempo.

A longitudinal data and nutritional questionnaire which include a 24 hour recall are not yet available to allow an assessment of the trend towards social dilution in physical growth resulting in stunting and wasting of older children of the present sample. We also do not know whether the change in mean heights and weights for boys in each socio-economic group is related to some change in nutritional practice. An understanding of the social customs, level of disease coupled with the lack of primary health care provide a basis for understanding and analysing the cause of poor growth in this population. The majority of the rural children travel long distances from their homes to school. Some leave for school without breakfast and spend the whole morning without food until 11 am or 12 noon. They are expected to perform all daily activities of the school on empty stomachs. Most rural boys do eat after school and leave to their respective places of work; others go to the fields for hunting, herding cattle and goats while some play on the sports field. Girls from rich families occasionally carry food in containers to school. After school they do housework at home where food is readily available. School feeding schemes are not practised in rural schools of South Africa. Most families in the rural areas depend on the government pension funds of the elderly for purchasing of food which amount to R350 or 87.5 US dollars per month. Most rich families in the area assist their relatives with food. This supports the findings of Steyn et al. (1992) that rural South African children have two meals a day with low energy intake.

In the current sample of children it would appear that stunting and wasting are most marked on the three socio-economic groups and there is no empirical evidence to suggest that this may be permanent. Social situations and nutritional intake of children in the ELS are currently being recorded (1999 and 2000), and in further analysis it will be possible to discover whether the change in the socio-economic situation really does have an effect on the growth of rural South African children.

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Typical sporadic occasion in Ellisras area

5

IS MALNUTRITION STABLE IN RURAL SOUTH AFRICAN CHILDREN?

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ABSTRACT

The aim of the study was to investigate the stability (tracking) of anthropometric indicators of the nutritional status of rural African children. In a prospective study, 523 boys and 451 girls, initially aged between 3 and 10 years, were followed over a period of three years. Indicators of nutritional status included height-for-age (HAZ), weight-for-age (WAZ) and weight-for-height (WHZ). Mean values of HAZ, WAZ and WHZ were low at all ages and indicated the existence of stunting and wasting. Correlation coefficients between the first and last measurements were generally high (r> 0.80), except for WHZ (r increased from 0.42 to 0.86 for boys and 0.59 to 0.80 for girls between 3 and 10 years of age). The generally low values for indicators of the nutritional status of rural South African children, seem to be stable over time. These findings are of real concern and implicate interventions to improve the nutritional status of rural South African children early in life.

Key words: Malnutrition, Ellisras rural children, stability, South Africa

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INTRODUCTION

Among children stunting (low height-for-age) indicates a chronic poor nutrition, while wasting (low weight-for-height) is a reflection of an acute poor nutritional condition (Cameron, De Wet, Ellison & Bogin, 1998). Stunting and wasting are major public health problems in developing countries, especially in Africa. They were reported to occur already during the period from birth to two or three years (Malina & Bouchard, 1991), while the long term consequences of stunting in childhood might be a loss of physical work capacity (Martorell, Rivera, Kaplovitz & Pollitt, 1992).

Despite the long-standing use of anthropometry for assessing growth and nutritional status of children in Africa based on cross-sectional studies, a number of issues remained unresolved. With the steady decline in food production in Africa (Jennings & Strret, 1989; Steyn, Robertson, Mekhuria & Labadarios, 1998), the stability of malnutrition from anthropometric indices in the life span of an African child has not been addressed. Ellisras rural children were reported to be stunted and wasted even at an older age (Monyeki, Cameron & Getz, 1997), with the absence of obesity either in terms of overweight or overfatness (Monyeki, van Lenthe & Steyn, 1999). They were not an exception from what was reported previously in other studies in Africa (Cameron, 1991; Cameron, Kgamphe, Leschener, Farrant, 1992; Monyeki, Pienaar & De Ridder, 1995). In these studies tracking of poor nutritional conditions was not examined due to the fact that the studies were cross-sectional.

Tracking can be defined as the stability of an indicator over time in an age- and sex-specific group of individuals (Twisk, Kemper, Van Mechelen & Post, 1997). More specifically, because tracking relates to the predictability of values later in life from earlier measurements, a tracking analysis can also be used to investigate the possibility of early detection of risk values for diseases.

Whilst most studies on growth and nutritional status of African children have been documented on infants and adolescents, the period between infancy and adolescence has received little attention. Nevertheless, it represents an important psychosocial and perhaps physical transitional period in the life of a child. In South Africa preschool children (aged 3 to 5 years) normally attend school from 9:00 to 13:00 hours from Monday to Friday and the schools are generally within short distances from their homes. Formal daily schooling for 6-12 year-old children is between 7:30 to 14:30 hours. However, because of the distance they have to travel daily to school, many of these primary school children leave home as early as 6:00 hours and return late in the afternoon (about 15:30 hours). For the majority of the children who start in the primary school, this period marks the end of total dependence on the mother and signifies their first interaction with a wider community through formal schooling. In situations in which meals are not provided at school this may also represent a time of nutritional transition to a more varied and perhaps less stable diet.

The South African government desires to improve the health of rural people. A major thrust of rural health programs is to control the influx of rural people to urban communities (Van der Merwe, 1988). This requires amongst others the availability of adequate data to monitor and evaluate the nutritional status of the children. The Ellisras Longitudinal Study (ELS) is a prospective cohort study, in which such data are periodically collected for rural children in the Northern Province of South Africa. The purpose of this report therefore, is to assess tracking of the nutritional conditions of Ellisras rural children aged 3 to 10 years by means of evaluating the stability of anthropometric indicators over a three-year period (1996-1998).

MATERIAL AND METHODS

A multiple longitudinal design, which means that measurements were repeated in more than one cohort with overlapping ages as in Twisk and Kemper (1995), was used (Figure 1). The sample was part of the ELS (Monyeki et al., 1999) comprising 451 girls and 523 boys aged 3 to 10 years who were measured repeatedly in Nov 1996 and Nov 1998.

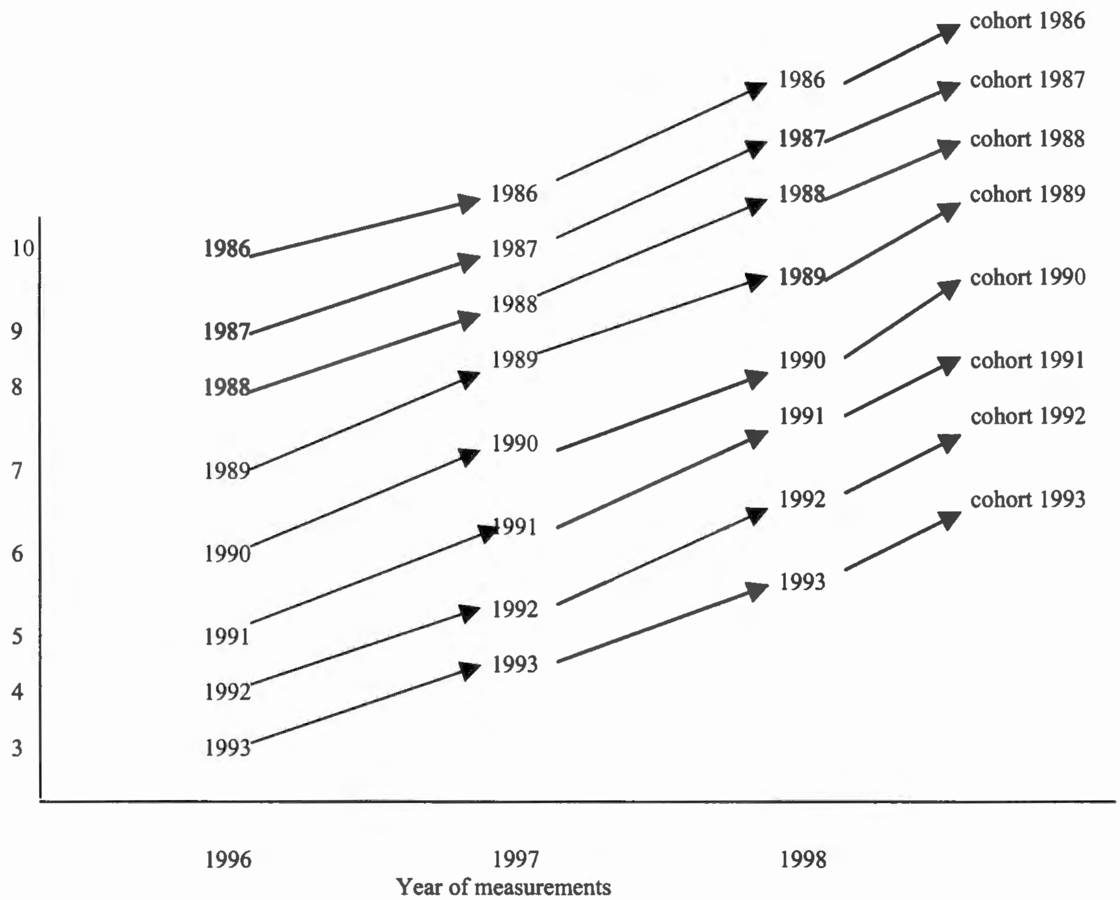

Figure1: Three year follow up (1996-1998) of 8 birth cohorts of 3 to 10 years ELS children

Measurements

Height and weight were measured according to the standard procedures discribed by the International Society for the Advancement of Kinanthropometry (ISAK) (Norton & Olds, 1996). A Martin anthropometer was used to measure height to the last complete 0.1cm and a Schoenle electronic scale to measure weight to the last complete 0.1kg. Before the survey was conducted all research team members participated in an intensive two weeks of special training course conducted by KD Monyeki (Level 3 – Criterion of ISAK). In all the surveys the intra-tester technical error of the measurement (TEM) (between two anthropometrist at the same station) ranged from 0.1 to 0.5cm for height and 0.1 to 0.2kg for weight. The inter-tester (anthropometrist and Level 3 criterion) TEM was between 0.1 to 0.3 cm for height while for weight was between 0 to 0.2kg. This falls within the recommendation of Borms, Hebbelinck, Carter, Ross & Lariviere (1979) and Ross & Marfell-Jones (1991) and Carter & Ackland (1994) and Norton & Olds (1996). Pearsons product-moment correlation were also used to show the reliability for each measurements. Intra and inter tester values for height and weight were r=0.98 (Bouchard, 1985, Ji & Ohsawa, 1996).

Statistical Analysis

Children who were measured in Nov. 1996 and Nov. 1998 were included in the analyses. Standard descriptive statistics of height, weight, HAZ, WAZ, and WHZ at baseline were determined. Height-for-age (HAZ), weight-for-age (WAZ) and weight-for-height (WHZ) values were based on the NHANES III reference sample (Frisancho, 1990).

Methodologically, a large variety exists in measurements of tracking studies (Twisk, Kemper & Mellenbergh, 1994; Van Lenthe, Kemper, Van Mechelen & Post, 1996). Several studies define the tracking coefficient as the correlation between parameters measured at the first and subsequent periods of measurement (Kemper, Snel, Verschuur, Storm-van Essen, 1991; Twisk et al., 1994; Van Lenthe et al., 1996). This traditional method of tracking has been previously used in other growth studies (Brown & Townsend, 1982; Bogin, Wall & Macvean, 1990). In this report, correlation coefficients were calculated for stunting (HAZ) and wasting (WHZ, WAZ) at the initial measurement of each birth cohort and at the measurement of the same birth cohorts three years later.

RESULTS

In tables 1 and 2 means and standard deviations of height, weight, and the WAZ, WHZ, HAZ (z-scores) at baseline levels are presented for both boys and girls. For boys mean HAZ z-scores range between –1.5 to 0.1 and WHZ z-scores range from –1.1 to –1.9

while mean HAZ z-scores range between –1.4 to -0.2 and WHZ z-scores range from –1.6 to –1.0 at the initial stage of the measurements for girls at ages 3 to 10 years. Mean WAZ

Table 1: Descriptive data of height, weight, HAZ, WAZ and WHZ for 523 ELS boys aged 3 to 10 years at the initial stage of the measurements

Age	N	Weight (kg) Mean (sd)	Height (m) Mean (sd)	HAZ Mean (sd)	WAZ Mean (sd)	WHZ Mean (sd)
3	24	13.3	1.00	0.1	0.2	-1.8
		(1.9)	(6.7)	(1.4)	(1.0)	(0.7)
4	65	14.2	1.04	-0.5	-0.7	-1.9
		(2.1)	(4.7)	(0.9)	(0.9)	(1.1)
5	71	16.2	1.12	-0.2	-1.2	-1.7
		(2.4)	(5.9)	(1.1)	(0.7)	(0.9)
6	112	18.1	1.17	-0.4	-1.2	-1.4
		(2.6)	(6.5)	(1.2)	(0.7)	(0.6)
7	121	19.5	1.21	-1.4	-1.3	-1.1
		(3.3)	(8.7)	(1.4)	(0.8)	(5.9)
8	76	21.0	1.26	-0.6	-1.3	-1.4
		(3.1)	(5.7)	(0.9)	(0.6)	(0.6)
9	42	22.8	1.30	-1.1	-1.3	-1.4
		(3.7)	(5.5)	(0.9)	(0.6)	(0.7)
10	12	22.0	1.36	-1.5	-1.7	-1.7
		(4.8)	(5.3)	(0.7)	(0.6)	(0.9)

HAZ = height-for-age ; WAZ = weight-for-age ; WHZ = weight-for-height. Based on Frisancho (1990).

Table 2: Descriptive data of height, weight, HAZ, WAZ and WHZ for 451 ELS girls aged 3 to 10 years at the initial stage of the measurements

Age	N	Weight (kg) Mean (sd)	Height Mean (sd)	HAZ Mean (sd)	WHZ Mean (sd)	WAZ Mean (sd)
3	20	12.9	1.00	-0.9	-1.0	-1.5
		(2.7)	(5.3)	(1.2)	(1.3)	(2.0)
4	46	13.7	1.04	-0.2	-1.4	-1.9
		(1.8)	(7.4)	(1.5)	(0.8)	(1.4)
5	59	15.6	1.10	-0.3	-1.2	-1.5
		(2.1)	(5.3)	(1.0)	(0.6)	(1.1)
6	119	17.4	1.17	-0.3	-1.2	-1.6
		(2.4)	(4.6)	(0.8)	(0.6)	(0.8)
7	124	19.0	1.22	-0.4	-1.3	-1.6
		(3.1)	(5.1)	(0.8)	(0.7)	(0.8)
8	52	20.1	1.25	-0.8	-1.2	-1.3
		(3.7)	(6.5)	(1.1)	(0.6)	(0.5)
9	22	21.7	1.27	-1.2	-1.3	-1.3
		(3.3)	(6.8)	(0.9)	(0.5)	(0.4)
10	9	21.8	1.31	-1.4	-1.6	-1.6
		(5.4)	(6.9)	(0.9)	(0.7)	(0.8)

HAZ = height-for-age ; WAZ = weight-for-age ; WHZ = weight-for-height. Based on Frisancho (1990).

Table 3: Percentage prevalence as determined by a Z-score value of less than –2 for weight-for-age (WAZ), height-forage (HAZ) and weight-for-height (WHZ) of Ellisras children

	Boys				Girls			
Age In years	N	HAZ (N) %	WHZ (N) %	WAZ (N) %	N	HAZ (N) %	WHZ (N) %	WAZ (N) %
3	24	(3) 12.5	(6) 25	(4) 16.7	20	(4) 20.0	(8) 40.0	(9) 45.0
4	65	(8) 12.3	(15) 23.1	(12) 18.5	46	(9) 19.6	(13) 28.3	(12) 26.1
5	71	(13) 18.3	(17) 23.9	(15) 21.1	59	(7) 11.9	(16) 27.1	(11) 18.6
6	112	(27) 24.1	(39) 34.8	(36) 32.1	119	(12) 10.1	(56) 47.1	(42) 35.3
7	121	(52) 42.9	(64) 52.9	(60) 49.6	124	(11) 8.8	(42) 33.9	(38) 30.7
8	76	(24) 31.6	(35) 46.1	(23) 30.3	52	(5) 9.6	(18) 34.6	(12) 23.1
9	42	(8) 19.1	(12) 28.6	(11) 26.2	22	(5) 22.7	(6) 27.3	(8) 36.4
10	12	(3) 25	(4) 33.3	(5) 41.6	9	(4) 44.4	(2) 22.2	(5) 55.6

z-scores ranges from -1.7 to 0.2 for boys and -1.9 to –1.3 for girls between the ages 3 and 10 years. The negative values of HAZ, WHZ and WAZ at almost all ages show that the values in our population are lower compared to the values in the NHANES study and suggest the prevalence of stunting and wasting in the Ellisras children. The high prevalence of stunting and wasting as seen by HAZ and WHZ for boys was 42.9 % and 52.9%, respectively at age 7. For girls, the high prevalence of stunting was reported at ages 9 (HAZ was 22.7%) and 6 (WHZ was 47.1%) (Table 3).

Tables 4 and 5 present the tracking coefficients for all anthropometric indicators. Generally, tracking coefficients are high for all indicators (r > 0.80), except for WHZ. For this indicator, the coefficients gradually increase from 0.42 to 0.86 for boys and 0.59 to 0.80 for girls.

Table 4: Tracking coefficients* (stability coefficient) over a three year period for height, weight, HAZ, WAZ and WHZ of Ellisras boys

Birth cohorts	Weight	Height	HAZ	WAZ	WHZ
3-5	0.82	0.94	0.94	0.82	0.42
4-6	0.88	0.84	0.84	0.88	0.72
5-7	0.87	0.93	0.93	0.87	0.63
6-8	0.85	0.95	0.95	0.85	0.64
7-9	0.88	0.92	0.92	0.87	0.75
8-10	0.82	0.92	0.94	0.86	0.71
9-11	0.82	0.92	0.92	0.82	0.74
10-12	0.87	0.95	0.95	0.87	0.86

* Pearson correlation between the first and the last measurements (1996-1998)

Table 5: Tracking coefficients* (stability coefficient) of weight, height, HAZ, WHZ and WAZ of Ellisras girls

Age	Weight	Height	HAZ	WHZ	WAZ
3-5	0.81	0.93	0.92	0.79	0.82
4-6	0.86	0.82	0.81	0.59	0.86
5-7	0.85	0.91	0.90	0.67	0.85
6-8	0.83	0.92	0.92	0.69	0.84
7-9	0.88	0.91	0.90	0.78	0.87
8-10	0.84	0.90	0.91	0.79	0.81
9-11	0.85	0.90	0.90	0.78	0.80
10-12	0.86	0.91	0.91	0.80	0.83

* Pearson correlation coefficient between first and last measurements (1996-1998)

DISCUSSIONS

To assess the predictability of poor nutritional conditions in longitudinal epidemiological studies, the concept of tracking is an important aspect to investigate. In the present study, most of the Ellisras children generally experience poor nutritional conditions. Based on the tracking analyses the present study further showed that indicators of a poor nutritional status are relatively stable over a period of three years.

A major problem in tracking analyses is the interpretation of the results. Generally, conclusions about the tracking phenomenon are based on the significance of tracking coefficient for the subjects at risk (Cameron, 1991) of either chronic or acute poor nutritional conditions. The magnitude of the tracking coefficients gives the most important information about the tracking phenomenon. However, tracking coefficients greatly depend on the initial measurements and the length of the period (Van Lenthe *et al.* 1996; Twisk et al., 1997). The short-term period used in the present study for tracking was reported to be reliable and accurate as compared to long-term periods as reported in other studies (Van Lenthe et al., 1996). Studies assessing tracking in height have been performed from adolescence to adulthood in Australia (Brown & Townsend, 1982), Belgium (Hauspie & Wachholder, 1986) and Guatemala (Bogin et al., 1990). A similar strong positive correlation (r around 0.80) was found for height in all the studies. However, studies evaluating anthropometric indicators of wasting and stunting in African populations are not available hence these results could not be compared to any such previous findings.

It appears that the acute and chronic poor nutritional conditions of the ELS children in this report do not improve but instead worsen with age. This contrasts with the findings of Malina and Bouchard (1991) who showed that children recover from their chronic poor nutritional conditions at the ages 2 or 3 years. Several factors such as social customs, Northern Province school feeding scheme which occasionally covers primary schools, level of disease coupled with the lack of primary health care provide a basis for understanding and analyzing the causes of poor nutritional status in this population. The majority of the rural children travel long distances to school daily. Some leave for school without breakfast and spend the whole morning without food until 11am or 12 noon. Consequently they perform all daily activities at school on empty stomachs. A report by Reitsma, Vorster, Venter, Labadarios, de Ridder and Louw (1994) indicates that feeding scheme had no influence on the growth of children in the rural suburbs of Johannesburg. Further research on daily nutrient intake of these children will give more substantial evidence to guide the intervention strategies aimed at improving the nutritional status of rural children in South Africa.

Healthy, active, well-nourished children are a fundamental pre-requisite for sustained economic development. If the conclusion about whether or not tracking exists depends on tracking coefficients, both chronic and acute poor nutritional conditions seems to track in this study. The strong positive tracking coefficients in this sample could enhance the prediction of future values for the subject who experiences acute and chronic poor nutritional conditions at the initial stage of the measurements. These findings prompt further investigation of young stunted and wasted children as a preventative strategy. Nevertheless, it seems important to take into account the fact that the high values for the indicators of wasting and stunting in this study are of major concern to the South African rural population. Therefore, interventions to improve the nutritional status of rural South African children should already be focussed on young children.

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Somototypes of children

6

STABILITY OF SOMATOTYPES: A LONGITUDINAL STUDY OF ELLISRAS RURAL BOYS.

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ABSTRACT

The purpose of this study was to investigate the stability of somatotypes in 451 Ellisras rural boys aged 6.5 to 8.5 years followed longitudinally for two and a-half years. The Heath-Carter anthropometric somatotypes, with stature correction for endomorphy, were calculated at six-month intervals for two and a-half years. Mean somatotype and somatotype attitudinal means were 1.9-2.9-4.2 (1.4), 1.9-2.6-4.0 (1.2), 1.9-3.1-4.4 (1.2), 2.3-2.8-4.3 (1.2), and 2.0-3.2-4.3 (1.1) at ages 6.5, 7.0, 7.5, 8.0 and 8.5 years respectively. The mean somatotypes shifted from balanced ectomorphy to mesomorphic ectomorph and vice versa over time. The average migratory distance (MD) was 6.1. The most stable boy had an MD of 2.3 and the least stable boys in the sample had an MD of 15.3. It is common for some children to have changes in somatotypes that are two or more times greater than other children. Endomorphy and ectomorphy had high significant inter-age partial correlations ($r>0.70$) while mesomorphy exhibited low insignificant partial correlation ($r<0.70$). The stability of somatotype components in Ellisras rural boys was evaluated in the light of fluctuations between ectomorphic mesomorph and balanced ectomorphy.

Key words: Stability, Somatotype, Elliras rural boys, Anthropometry

INTRODUCTION

Physique has been useful in assessing the outcomes of underlying growth and maturity processes, which leads to a better understanding of variation in both child and adult physique. The question of stability of physique throughout these processes has been investigated in only a limited manner in the Northern Hemisphere (Walker and Tanner, 1980; Bok and Tlapakova, 1982; Claessens et al., 1986; Malina and Bouchard, 1991; Hebbelinck et al., 1995; Carter et al., 1997), while in Africa it has never been reported. Carter and Heath (1990) showed the importance of examining patterns of individual children in addition to group averages. This is because some children changed in one direction while others changed in the opposite direction, thus confounding individual changes. Longitudinal studies on change of somatotypes provide valuable information on the somatotype stability. Carter and Heath (1990) and Hebbelinck et al. (1995) reported that both individual and group somatotypes change with age; individual patterns of change are important but might be masked by group variability. Longitudinal studies are needed to provide a better basis for understanding overall physique changes in growing children since most of the studies on somatotype are cross-sectional.

It appears that the somatotype of some children are fairly stable over a specific period in their growth (Bok and Tlapakova, 1982; Claessens et al., 1986; Carter and Heath, 1990). Group means and distribution of somatotypes showed that in general somatotypes of boys progress from endomorph mesomorph towards balanced mesomorph, after which they tend to decrease in mesomorphy and increase slightly in ectomorphy. Eventually there is a reversal towards ecto-mesomorphy, balanced mesomorphy or endo-mesomorphy (Carter and Heath, 1990). However, it was reported that in a cross-sectional study of Ellisras rural boys aged 3 to 10 years, the boys consistently had high ectomorphy ratings with lower mesomorphy ratings and extremely low endomorphy ratings (Monyeki et al., 1999a). In a prospective study of Ellisras rural children, it was possible to examine the extent to which this population fits within the model proposed by Carter and Heath (1990).

Although there are genetic factors in the development of somatotype components, nutrition and exercise play an important role (Carter and Heath,1990). The existence of a high prevalence of chronic and acute poor nutritional conditions (Monyeki et al., 1997) and non-existence of obesity, either in terms of overweight or overfatness was reported in a cross-sectional sample of Ellisras rural boys (Monyeki et al., 1999b). The need to assess these boys over a six-month interval was important even though somatotypic differences in adjacent years were often reported to be small. Differences are evident at two years or more intervals (Carter and Heath, 1990). The purpose of this report was to investigate the stability of somatotype in Ellisras rural boys aged 6.5 to 8.5 years (mean age at each period of measurement) during a period of two and a-half years.

MATERIALS AND METHODS

Sample size

The sample was part of the Ellisras Longitudinal Study (Monyeki et al., 1999b) which is a mixed- longitudinal study design aimed at examining the nutritional status, and identifying the pre-pubertal and pubertal velocity growth curves of Ellisras rural community children.

Table 1:Number of subjects in each birth cohort for Ellisras rural boys

Birth cohorts	N
1986	9
1987	27
1988	76
1989	130
1990	94
1991	54
1992	47
1993	14
Total:	451

The sample was drawn from 22 schools (10 pre-school and 12 primary schools) randomly selected from 68 schools in Ellisras region and they comprised 451 boys randomly selected from pre-school and primary school children aged 3-10 years (born from 1986 to 1993) (Monyeki et al., 1999b). The sample sizes in each birth cohort are summarized in table 1. These subjects completed all the five consecutive measurements twice yearly

(May and Dec) over a period of two and a-half years (i.e. between Dec 1996 and Dec 1998). For the purpose of this study the mean age of the children was used for each period of measurements. Thus at the beginning of the study the mean age was 6.5 years and increased half yearly to 8.5 years after 2.5 years. For instance, the age range for the mean age of 6.5 years was from 3 to 10 years and for mean age of 7.5 years was from 3.5 to 10.5 years (Table 2).

Anthropometric assessment

All children within the selected age group underwent measurements of height, weight, body circumferences (calf, arm flexed and tensed), breadths (bi-epicondylar humerus and femur) and skinfolds (triceps right, subscapular, supraspinale, calf) according to standard procedures suggested by the International Society for the Advancement of Kinanthropometry (ISAK) (Norton and Olds, 1996). A Martin anthropometer was used to measure height to the last complete 0.1cm, a Schoenle electronic scale to measure weight to the last complete 0.1kg, a steel tape was used for circumference measurements complete to 0.1cm, a spreading calliper for breadth measurements taken to the last 0.1cm, and Harpenden (John Bull) skinfold callipers with inter-jaw pressure of $10g/mm^2$ surface jaw face area for skinfolds measurements to the last completed 0.2mm. Before the survey was conducted all research team members participated in an intensive two weeks of special training course conducted by one of the authors KDM (Level 3 – Criterion of ISAK). Even though Norton and Olds (1996) and Carter and Ackland (1994) have reported the effects of the magnitude of the technical error of the measurement (TEM) on the magnitude of derived variables such as somatotype, it was possible to train team members to have TEMs for somatotype variables that are within the acceptable standards. In all the five surveys the intra-tester TEMs (between two anthropometrists at the same station) for endomorphy was 0.15, mesomorphy 0.13 and 0.03 units for ectomorphy rating. The inter-tester (anthropometrist and Level 3 criterion) TEMs for somatotype components was 0.13, 0.10 and 0.05 respectively. Pearson's product-moment correlations were also used to show the reliability for each somatotype component. The intra tester r values for somatotype components was 0.91, 0.93 and 0.96 while the inter tester r values was 0.90, 0.94 and 0.92 respectively. The 0.0 to 0.2 range of somatotype intra and inter tester technical error of measurements as, also reported earlier on by Bouchard (1985), was less than a fraction of the sample variance.

All the subjects were somatotyped using the Heath-Carter anthropometric somatotype method (Carter and Heath, 1990). This method was reported to be applicable for the description of variation in the human species regardless of age, sex or different attribute of climate, diet, genetics, race, health or physical activity (Heath and Carter, 1971; Carter, 1996; Hebbelinck et al., 1973). The sum of the three skinfolds was adjusted for body size by multiplying it with 170.18/height (in cm) before determining the endomorphy ratings (Heath and Carter, 1967; Carter and Heath, 1990). Calculations of somatotype attitudinal means (SAM), based on somatotype attitudinal distance (SAD) were performed using the special procedures for somatotype analyses (Carter *et al.*, 1983; Carter and Heath, 1990).

Cressie et al. (1986) claimed that using the SAD, which is the distance between any two somatopoints in three dimensions, pre-maturely collapses the three-components somatotype vector into scalar SAD value, thereby reproducing the degree of freedom for the F-ratio. They suggest increasing the degree of freedom to include those for the three components as separate variables (Cressie, 1998;1999), thus increasing the likelihood of type I errors when compared with the method of Carter et al. (1983). Their basic premise was that the three-somatotype components should be considered together in a one-way MANOVA. As a test of the whole somatotype, their premise was argued to be false by Carter et al. (1998, 1999) because it denies the integrity of the whole somatotype and erroneously increases the degrees of freedom. Furthermore, Cressie (1998, 1999) argued that the SAD should be treated as any other derived variables and not be assigned degrees of freedom based on the variables from which it is derived. The procedures of Cressie et al. (1986) are not applicable to analysis of somatotype but could be applied as a secondary analysis to the separate components. However, they are not appropriate for the repeated measures analysis of the whole somatotype (Carter et al., 1997) as used in this study.

Statistical Analysis

Prior to the final analysis the possible existence of cohort effects was tested. From the multiple longitudinal design, eight cohorts consisting of individuals born in 1986 to 1993 could be identified (Monyeki et al., 1999b). MANOVA for repeated measurements was performed to test for the differences in the development of SADs (Carter et al., 1983) between the cohorts. Considering $p<0.01$ as statistically significant, no cohort effects were found. Time-of-measurement effect was tested using MANOVA at a significant level of $p<0.01$ for the SADs (Carter et al., 1983). No significant differences were found. Due to the absence of cohorts and time-of-measurement effect the somatotype variables were presented according to the period of measurements (mean age at each period of measurement).

Descriptive statistics for the three-somatotype components were calculated at each period of measurements. The anthropometric somatotype with a stature correction for endomorphy was calculated using the equation recommended by Hebbelinck et al. (1973) and Carter and Heath (1990). Frequency and percentage frequency for the somatotype categories were calculated at each measurement period. Somatotype ANOVAs for repeated measures were calculated using SADs between adjacent six-month periods to measure changes at six-month interval in individual somatotype. In addition to analysing the somatotype as a whole using three-dimensional distances between individual and group somatotypes, the components were also analysed separately. In order to examine the stability of each somatotype component from ages 6.5 to 8.5 years, a series of second-order partial correlations was computed for one somatotype component between six month interval, while holding the other two constant at the initial measurement (Carter et al., 1997; Hebbelinck et al., 1995). For instance, in assessing the stability of endomorphy over a 2.5 year period, the mesomorphy and ectomorphy components were held constant at the baseline. Therefore, it was possible to determine the inter-age correlations between endomorphy ratings at each period of measurements.

RESULTS

Means and standard deviations for each of the somatotype components (endomorphy, mesomorphy, ectomorphy) as well as somatotype attitudinal means (SAM) are presented in Table 2 while mean somatotypes are plotted on a somatochart in Figure 1. The SAMs gradually decreased from 1.4 to 1.1 and the mean age from 6.5 to 8.5 years (Table 2).

Table 3 presents the frequency and percentage frequency in somatotype categories for Ellisras rural boys for the five measurement periods.

Table 2: Mean and standard deviations of somatotypes and somatotype attitudinal means (SAMs) for Ellisras rural boys (N=451)

Age Range		Mean age in years	Endo	Meso	Ecto	SA M[a]	Ht[b] (cm)	Wt[b] (kg)
3.0-10.0	m	6.5	1.9	2.9	4.2	1.4	117.9	18.4
	sd	1.6	0.5	0.9	1.4	0.8	8.2	3.8
3.5-10.5	m	7.0	1.9	2.6	4.0	1.2	120.6	20.1
	sd	1.6	0.4	0.8	1.2	0.6	8.1	4.1
4.0-11.0	m	7.5	1.9	3.1	4.4	1.2	124.0	21.3
	sd	1.6	0.5	0.9	1.1	0.6	9.1	4.2
4.5-11.5	m	8.0	2.3	2.8	4.3	1.2	126.1	22.5
	sd	1.6	0.6	0.8	1.1	0.6	9.9	4.4
5.0-12.0	m	8.5	2.0	3.2	4.3	1.1	128.6	23.8
	sd	1.6	0.5	0.7	1.0	0.6	9.7	4.5

[a] Somatotype attitudinal mean, [b] Ht= Height in cm and Wt= Weight in kg

Table 3: Frequency (n) and percentage frequency (%) of somatotype categories of Ellisras rural boys (N=451)

	Age in years				
	6.5	7.0	7.5	8.0	8.5
Somatotype Category	n (%)	n (%)	n (%)	n (%)	n (%)
1 Balanced endomorph		1 (0.2)		4 (0.9)	
2 Mesomorphic endomorph	1 (0.2)	1 (0.2)	1 (0.2)		
3 Mesomorph endomorph	11 (2.4)	1 (0.2)	3 (0.7)	3 (0.7)	3 (0.7)
4 Endomorphic mesomorph	12 (2.7)	12 (2.7)	8 (1.8)	7 (1.6)	4 (0.9)
5 Balanced mesomorph	36 (8.0)	31 (6.9)	24 (5.3)	34 (7.5)	31 (6.9)
6 Ectomorphic mesomorph	12 (2.7)	16 (3.5)	17 (3.8)	8 (1.8)	19 (4.2)
7 Mesomorph ectomorph	75 (16.6)	87 (19.3)	113 (25.1)	85 (18.8)	128(28.4)
8 Mesomorphic ectomorph	141 (31.3)	98 (21.7)	168 (37.9)	75 (16.6)	142(31.5)
9 Balanced ectomorph	117 (25.9)	180 (39.9)	106 (23.5)	193 (42.8)	103(22.8)
10 Endomorphic ectomorph	23 (5.1)	11 (2.4)	4 (0.9)	21 (4.7)	4 (0.9)
11 Endomorph ectomorph	4 (0.9)	2 (0.4)		5 (1.1)	
12 Ectomorphic endomorph					
13 Central	19 (4.2)	11 (2.4)	7 (1.6)	16 (3.5)	17 (3.8)

The mean ectomorphy was high at each age (Table 2). Ellisras rural boys exhibit highest percentage frequency of 31.3% (mesomorphic ectomorph), 39.9% (balanced ectomorph), 37.9% (mesomorphic ectomorph), 42.8% (balanced ectomorph) and 31.5%. (mesomorphic ectomorph) at each age respectively. The two highest percentage frequencies are in the balanced ectomorphy and mesomorphic ectomorph category in four out of five age groups (Table 3).

Table 4 shows the F-ratios of differences between SAD in Ellisras rural boys. F-ratios range from 2.3 to 74.0 at the different measurement periods. At the $p<0.01$ level there was no significant difference in SAD between 7.0 and 8.0 years as was the case also with the 7.5 and 8.0 years. It is interesting to note that the greater the age interval the larger the F-ratio. The 6.5 years age group differed significantly from all the other age groups (Table 4).

Dispersion of somatotypes about their mean and analysis by separate components.

Somatoplots are two-dimensional projections of the three-component somatotype, hence it is likely that the true distance between somatotypes is distorted. Therefore the distance between somatotypes was calculated using the three-dimensional somatotype attitudinal distance which is a true distance in any orthogonal system in component units between any two somatotypes (Carter et al., 1983; Carter and Heath, 1990). Table 5 presents differences among somatotype components.

Table 4: SADs (above the diagonal) among the mean somatotypes difference by age group and the associated F-ratios (below the diagonal) for repeated measurement of Ellisras rural boys (N=451)

Age in years	6.5	7.0	7.5	8.0	8.5
6.5	-	0.23	0.17	0.19	0.30
7.0	65.6*	-	0.06	0.36	0.50#
7.5	30.3*	6.3*	-	0.12	0.12
8.0	29.2*	2.3	2.5	-	0.12
8.5	74.0*	7.3*	27.0*	31.4*	-

* indicate significant difference ($P < 0.01$)
\# Differ by more than 0.5 or more units

Repeated measures (ANOVAs) for the three components were used to test the difference between means (Table 5). There was a slight increase in endomorphy ($F=56.12$) from 6.5 years to 8.5 years (1.9 to 2.3) which reached the level of significant difference ($p<0.01$) at the age of 8.0 years and 8.5 years. Endomorphy was lower than mesomorphy and ectomorphy at all ages. There was a gradual increase from 2.6 at 7.0 years to 3.2 at 8.5 years in mesomorphy ($F=34.90$). The mesomorphy of 3.1 at 7.5 years differed significantly ($p<0.01$) from other ages except for 8.5 years. Even though ectomorphy ($F=5.74$) was high in all the age groups compared to endomorphy and mesomorphy, insignificant differences were found between the different age groups.

Table 5: Differences among somatotype components for repeated measurements of Ellisras rural boys (N=451)

Somatotype variables	Age in years (mean somatotype values)				
Endomorphy	6.5 (1.9)	7.0 (1.9)	7.5 (1.9)	8.0 (2.3)	8.5(2.0)
Mesomorphy	6.5 (2.9)	7.0(2.6)	7.5 (3.1)	8.0 (2.8)	8.5 (3.2)
Ectomorphy	6.5 (4.2)	7.0 (4.0)	7.5 (4.4)	8.0 (4.3)	8.5(4.3)

[a]Values underlined are homogeneous, but are significantly different from others.

Table 6: Inter age partial correlation's in Ellisras rural boys for somatotype[c] components at each period of measurements with mesomorphy and ectomorphy held constant at the lowest value (N=451, * =r>0.70)

	Age in years											
	6.5			7.0			7.5			8.0		
7.0	0.89*	0.67	0.83*									
7.5	0.82*	0.66	0.75*	0.89*	0.61	0.87*						
8.0	0.78*	0.50	0.71*	0.81*	0.49	0.82*	0.89*	0.36	0.90			
8.5	0.74*	0.49	0.66	0.80*	0.56	0.75*	0.86*	0.44	0.84	0.85*	0.68	0.89*

[c]Values are presented as partial correlations for endomorphy, mesomorphy and ectomorphy for each age group.

Migratory Distance (MD)

When somatotypes are followed over time the distance and direction of their path can be quantified (Carter and Heath, 1990). Stability of individual somatotypes is best shown by the sum of the SADs between a sequence of somatotypes obtained over the period of two and a-half years. This is referred to as the migratory distance (MD) and it is calculated in component units (Carter et al., 1990; Carter and Heath, 1990). In this study the average MD was 6.1. The most stable boy had an MD of 2.3 and the least stable boy in the sample had an MD of 15.3. It is common for some children to have changes in somatotype that are two or more times greater than that of other children (Hebbelinck et al., 1995).

Partial correlation

Calculating inter-age partial correlations for one somatotype component while holding the other two components constant assessed the stability of each component. Ten correlations were calculated for each somatotype component and the results are presented in Table 6. A correlation coefficient value r>70 were found to be significant. This value had an r^2 of 0.49 or 49% common variance but was only 29 % better than chances in predicting the component values. Endomorphy (10/10) and ectomorphy (9/10) had the most significant correlations (r>0.70) while mesomorphy (0/10) had insignificant correlations (Table 6).

DISCUSSIONS

In this study, longitudinal results of anthropometric measurements carried out twice yearly for two and a-half years in rural Ellisras boys in South Africa, with particular emphasis on the stability of somatotypes are presented. The study showed that some of the Ellisras rural boys are stable while others are extremely variable with changes of two to six times greater than the most stable children are. The mean somatotypes shift from balanced ectomorphy to mesomorphic ectomorph and vice versa over time.

The findings of this study deviate from the model presented by Carter and Heath (1990), which was based on both longitudinal and cross-sectional studies done in various countries. The model shows that in general, the somatotype of boys progress from endo-mesomorphy towards balanced mesomorphy between the ages of 2 to 6 years and from age 6 to mid-adolescence boys tend to increase in mesomorphy and increase slightly in ectomorphy. In the present sample ectomorphy components were dominant throughout the period of measurements with the rating from 4.0 to 4.4 while mesomorphy ranged from 2.6 to 3.1 and endomorphy being fairly low with ratings from 1.9 to 2.3 (Table 2).

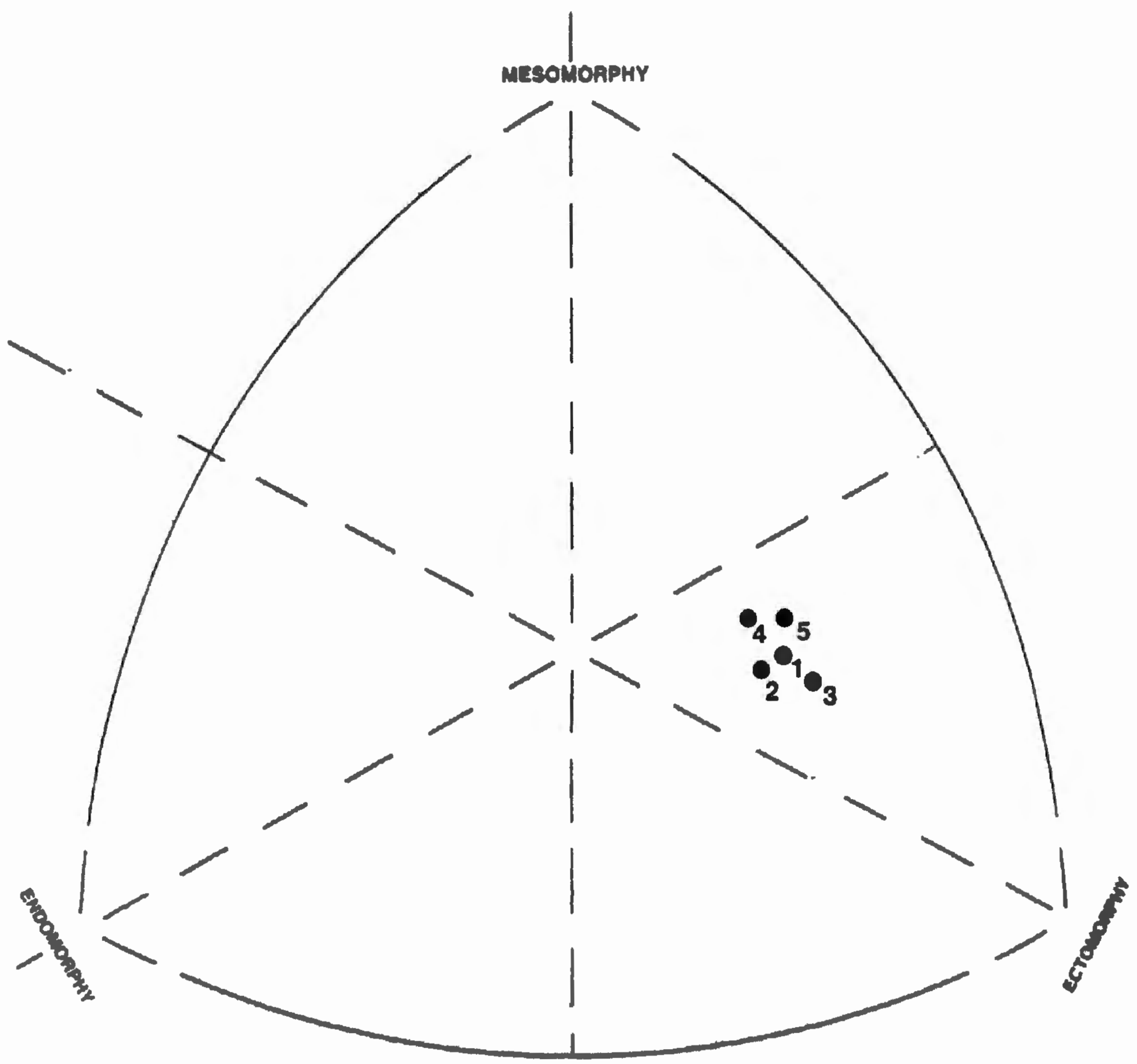

Figure 1: Mean somatotypes of Ellisras rural boys
(1 = 6.8 years; 2= 7.3 years, 3 = 7.8years, 4= 8.3 years, 5 = 8.8years)

Stability greatly depends on the initial measurement and the length of the period in most studies (Van Lenthe et al., 1996; Twisk et al., 1997). The short-term period used in the present study for the stability of somatotype was reported to be reliable and accurate as compared to long term period in other studies (Carter and Heath, 1990; Hebbelinck et al., 1995). The inter-age partial correlations for endomorphy and ectomorphy were high and significant between adjacent period and longer period. They were similar to the high correlation found between 0.5 to 0.8 for the Harpenden Growth study among boys aged 5 to 14 years (Walker and Tanner, 1980).

The larger SAMs between age 6.5 to 8.5 years (mean=1.2 sd 0.6 to 1.4; SD= 0.8) and the high relationship between somatotype ratings for younger (6.5 years) and older (8.5 years) boys in the present study possibly reflect differences in timing of variations in growth and maturation within the sample as it was reported by Malina and Bouchard (1991). Subsequently, Malina and Bouchard (1991) and Carter and Heath (1990) reported that some environmental factors like nutrition, exercise, health practice, disease and the timing of biological maturation influence changes in physique. Ellisras rural boys were dominant in balanced ectomorphy (22.8 to 42.8%) and mesomorphic ectomorph (16.6 to 37.9%) thoughout the age period. An understanding of the social customs, level of disease coupled with the lack of primary health care could provide a basis for explaining the high percentage frequency in the balanced ectomorphy and mesomorphic ectomorph category. A complexity of social customs and practices surrounding boys in rural areas of the Northern Province of South Africa constitutes one of the major factors leading to high ectomorphy in the sample. The majority of the rural children travel long distances from their homes to school. Some leave for school without breakfast and spend the whole morning without food until 11 am or 12 noon. They are expected to perform all daily activities of the school on empty stomachs. Most rural boys do eat after school and leave to their respective places of work: Some go to the fields for hunting, herding cattle and goat while others play on the sports field. With the decline of food in Africa (Jennings and Strret, 1989; Steyn et al., 1998) rural South African children were reported to have two meals a day with low energy intake (Steyn et al., 1992). Additional studies are needed to determine the role of genetics and environment in answering the question why some children's somatotype is more stable than others, that is, is there a heritability of stability?

CONCLUSION

In general, based on the analysis and within the limitations of the study, the results of the Ellisras Longitudinal Study lead to the following conclusions:

- Majority of the somatotypes of the present sample fluctuate between ectomorphic mesomorph and balanced ectomorphy over time.
- Migratory distances showed that the somatotype of some boys are stable while those of others vary with changes up to two or more times greater than the most stable boys.
- The inter-age partial correlations for endomorphs and ectomorphy are high and significant but low and insignificant in mesomorphy.

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Stability of somatotypes in 4- to 10 year-old rural South African girls

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Summary. In 1996, a mixed longitudinal study (ELS) was initiated to assess the stability of somatotypes in 408 girls who comprised 99 pre-school and 309 primary school children in Ellisras rural area in the Northern Province of South Africa. The children's somatotype was assessed using the Heath-Carter (1990) anthropometric method. Anthropometric dimensions were taken according to the protocol of the International Society for the Advancement of Kinanthropometry (ISAK). The most stable pre-school and primary school girl had migratory distance (MD) of 2.6 and 3.4 respectively while the least stable pre-school and primary school girl had MD of 17.9 and 24.4, respectively. The mean somatotype shifted from mesomorph-ectomorph to balanced ectomorph category for pre-school girls and from mesomorphic ectomorph as well as mesomorph-ectomorph to balanced ectomorph in primary school girls. The inter-age partial correlations for endomorphy and ectomorphy were high and significant, but insignificant with regard to mesomorphy

Key words: Stability, somatotype, girls, growth, anthropometry, South Africa

Introduction

Somatotyping, one of the most useful techniques of evaluating physique characteristics, is a quantification of the present shape and composition of the human body. The somatotype is rated in three components, that is, endomorphy (relative fatness), mesomorphy (relative musculoskeletal robustness) and ectomorphy (relative linearity). According to Carter and Heath (1990), the somatotype is an overview of the total physique, which is independent of body size. In growth studies, evaluation of the somatotype is particularly important in providing estimates of changes over time associated with children's growth and development.

Previous research studies have shown that changes in somatotype in children can provide valuable information for understanding their growth and maturity. For instance, Parizkova and Carter (1976) stressed the importance of assessing patterns of growth in individual children rather than relying on group means. This is based on the finding that whilst some children changed in one direction, others changed in opposite direction, thereby confounding individual changes in the group. They concluded that longitudinal studies are more reliably provide a basis for understanding of overall physique changes in children. In a comprehensive review of longitudinal studies on development and change in somatotype, Carter and Heath (1990) concluded that both individual and group somatotypes changed with age and that individual patterns of change are important but could be masked by group variability (Walker and Tanner, 1980; Bok and Tlapakova, 1982; Claessens *et al.*, 1986).

Carter and Heath (1990) provided a model of the general pathway of children's somatotypes from infancy to adulthood. This schematic model quantifies the existence of somatotype and sexual dimorphic patterns for both groups and individuals during growth and development. In studies carried out on Belgian children, Duquet (1980) assessed the somatotypes of boys and girls aged 6-13 years and Claessens *et al.* (1986) somatotyped boys from 13-18 years using a modified Sheldon technique. From these studies it was concluded that individual somatotypes were relatively stable but that there was a slight variation in the mean somatotypes of the group.

Several studies have been carried out to evaluate the anthropometric and body composition characteristics of South African children. These studies have mainly focused on obesity

(Monyeki *et al.*, 1999a), fat patterning (Cameron et al., 1992) and somatotype (Monyeki *et al.*, 1999b). However in these studies, longitudinal changes in somatotype were not investigated. Although there are genetic factors involved in the development of physique, nutrition and physical exercise also play an important role (Smith et al., 1973; Bouchard and Lortie, 1984).

While most studies on growth and nutritional status of African children have been documented on infants and adolescents, the period between infancy and adolescence has received little attention. Nevertheless, it represents an important psychosocial and perhaps physical transitional period in the life of a child. Studies of the Ellisras rural children in South Africa have consistently shown prevalence of chronic and acute poor nutritional condition in the children (Monyeki *et al.*, 2000). The need to assess children over six months interval is important, even though somatotypic differences in adjacent years were often reported to be small, since differences are evident at intervals of two years or more (Carter and Heath, 1990). This study was carried out therefore, to assess the stability of the somatotype in pre-school (4 to 6 years) and primary school (8 to 10 years) girls in Ellisras rural area of South Africa.

2. Subjects and Methods

2.1 Subjects

The sample was part of the Ellisras Longitudinal Study (Monyeki et al., 1999b) which is a mixed- longitudinal study design aimed at examining the nutritional status, and identifying the pre-pubertal and pubertal velocity growth curves of Ellisras rural community children. The sample was drawn from 22 schools (10 pre-school and 12 primary schools) randomly selected from 68 schools in Ellisras region and they comprised comprised 408 pre-school and primary school girls aged 3-10 years, who participated in the Ellisras Longitudinal Study (ELS) (born from 1986 to 1993) (Monyeki et al., 1999b). The sample sizes in each birth cohort are summarised in table 1. These subjects completed all the five consecutive measurements twice yearly (May and November). For the purpose of this study the mean age of the children was used for each period of measurement. Thus at the beginning of the study the mean age was 4 years and 8 years for pre-school and primary school children, respectively and increased half yearly to 6 and 10 years respectively after 2 years. For instance, the age range for the mean age of 4 years was from 3 to 5 years and 8 years from 6 to 10 years (Table 2) there were 99 pre-school and 309 primary school girls who were followed longitudinally from age 4 and 6 years, respectively.

Table 1:Number of subjects in each birth cohort for Ellisras rural girls

Birth cohorts	N
1986	8
1987	21
1988	48
1989	122
1990	110
1991	49
1992	33
1993	17
Total:	408

2.2 Anthropometric measurements

All children within the selected age group underwent measurements of height, weight, body circumferences (calf, arm flexed and tensed), breadths (bi-epicondylar humerus and femur) and skinfolds (triceps right, subscapular, supraspinal, calf) according to standard procedures suggested by the International Society for the Advancement of Kinanthropometry (ISAK) (Norton and Olds, 1996). A Martin anthropometer was used to measure height to the last complete 0.1cm, a Schoenle electronic scale to measure weight to the last complete 0.1kg, a steel tape was used for circumference measurements complete to 0.1cm, a spreading calliper for breadth measurements taken to the last 0.1cm, and Harpenden (John Bull) skinfold callipers with inter-jaw pressure of 10g/mm^2 surface jaw face area for skinfolds measurements to the last completed 0.2mm. Before the survey was conducted all research team members participated in an intensive two weeks of special training course conducted by one of the authors KDM (Level 3 – Criterion of ISAK). Even though Norton and Olds (1996) and Carter and Ackland (1994) have reported the effects of the magnitude of the technical error of the measurement (TEM) on the magnitude of derived variables such as somatotype, it was possible to train team members to have TEMs for somatotype variables that are within the acceptable standards. In all the five surveys the intra-tester TEMs (among three measurements by the anthropometrist at the same station) for endomorphy was 0.15, mesomorphy 0.13 and 0.03 units for ectomorphy rating. The inter-tester (anthropometrist and Level 3 criterion) TEMs for somatotype components was 0.13, 0.10 and 0.05 respectively. Pearson's product-moment correlations were also used to show the reliability for each somatotype component. The intra-tester r values for somatotype components were 0.91, 0.93 and 0.96 while the inter-tester r-values were 0.90, 0.94 and 0.92, respectively. The 0.0 to 0.2 range of somatotype intra- and inter- tester technical error of measurements noted for the somatotype is consistent with those reported by Bouchard (1985) as less than a fraction of the sample variance.

All the subjects were somatotyped using the Heath-Carter anthropometric somatotype method (Carter and Heath, 1990). This method was reported to be applicable for the description of variation in the human species regardless of age, sex or different attribute of climate, diet, genetics, race, health or physical activity (Heath and Carter, 1971; Carter and Heath, 1990; Carter, 1996; Hebbelinck et al., 1973). The sum of the three skinfold was adjusted for body size by multiplying it with 170.18/height (in cm) before determining the endomorphy ratings (Heath and Carter, 1967; Carter and Heath, 1990). Calculations of somatotype attitudinal means (SAM), based on somatotype attitudinal distance (SAD) were performed using the special procedures for somatotype analyses (Carter *et al.*, 1983; Carter and Heath, 1990).

Cressie et al. (1986) claimed that using the SAD, which is the distance between any two somatopoints in three dimensions, pre-maturely collapses the three-components somatotype vector into scalar SAD value, thereby reducing the degrees of freedom for the F-ratio. They suggest increasing the degree of freedom to include those for the three components as separate variables, thus increasing the likelihood of type I errors when compared with the method of Carter et al. (1983). Their basic premise was that the three-somatotype components should be considered together in a one-way MANOVA. As a test of the whole somatotype, their premise was argued to be false by Carter et al. (1998) and Carter and Duquet (1999) because it denies the integrity of the whole somatotype and erroneously increases the degrees of freedom. Furthermore, Cressie (1998, 1999) argued that the SAD should be treated as any other derived variables and not be assigned degrees of freedom based on the variables from which it is derived. The procedures of Cressie et al. (1986) are not applicable to analysis of somatotype but could be applied as a secondary analysis to the separate components. However, they are not appropriate for the repeated measure analysis of the whole somatotype (Carter et al., 1997) as used in this study.

Statistical Analysis

Prior to the final analysis the possible existence of cohort effects was tested. From the multiple longitudinal design, eight cohorts consisting of individuals born in 1986 to 1993 could be identified (Monyeki et al., 1999b). MANOVA for repeated measurements was performed on the SADs to test for any significant differences (Carter et al., 1983) between the cohorts. Considering $p<0.01$ as statistically significant, no cohort effects were found in each group. Time-of-measurement effect was tested using MANOVA at a significant level of $p<0.01$ for the SADs (Carter et al., 1983). No significant differences were found in each age group. Due to the absence of cohort effects and time-of-measurement effect the somatotype variables were presented according to the period of measurements (mean age at each period of measurement for the pre-school and primary school girls).

Descriptive statistics for the three-somatotype components were calculated at each period of measurements. The anthropometric somatotype with a stature correction for endomorphy was calculated using the equation recommended by Hebbelinck et al. (1973) and Carter and Heath (1990). Frequency and percentage frequency for the somatotype categories were calculated at each measurement period. Somatotype ANOVAs for repeated measures were calculated using SADs of the mean somatotype between adjacent interval to examine any significant changes in three-dimensional distances between individual and group somatotypes. In order to examine the stability of each somatotype component from ages 6.5 to 8.5 years, a series of second-order partial correlations was computed for one somatotype component between six month interval, while holding the other two constant at the initial measurement (Carter et al 1997; Hebbelinck et al., 1995). For instance, in assessing the stability of endomorphy over two years period, the mesomorphy and ectomorphy components were held constant at the baseline. Therefore, it was possible to determine the inter-age correlations between endomorphy ratings at each period of measurements.

Results

Means and standard deviations for each of the somatotype components (endomorphy, mesomorphy, ectomorphy) as well as somatotype attitudinal means (SAM) are presented in Table 2 while mean somatotypes are plotted on a somatochart in Figure 1. Table 3 presents the frequency and percentage frequency of somatotype categories for Ellisras rural pre-school and primary school girls over the five measurement periods.

The mean ectomorphy is high (4.4 to 4.6) at each age for primary school girls while mean mesomorphy and ectomorphy varies between 3.3 and 3.8 with endomorphy being slightly lower for the pre-school girls. (Table 2). The highest percentage frequency range of 17.2 and 37.4% was exhibited in the mesomorph- ectomorph category of pre-school girls while primary school girls were dominant in the balanced ectomorphy category (39.8 to 58.6%) for the entire period of the measurements (Table 3).

Table 4 shows the F-ratios of SADs for repeated measurements of pre-school and primary school girls. F-ratios range from 0.0 to 37.2 for pre-school girls and 0.5 to 43.6 for primary school girls at the different measurement periods. At the $p<0.05$ level there was no significant difference in mean somatotypes of some adjacent period of measurement (4.5 and 5; 5.5 and 5) for pre-school girls. For primary school girls, no significant difference ($p<0.05$) was observed between those somatotype which are farther apart (8.5 and 9.5; 8.5 and 10 age categories). Both the 4 and the 8-year-old differed significantly from the other age groups respectively (Table 4). It is important to note that the greater the age interval the larger the F-ratio.

Table 2: Descriptive statistics of height, weight, somatotype components and SAMs for preschool (4 to 6 years) and primary school (8 to 10 years) Ellisras rural girls

		Pre-school, N=99					Primary school, N=309				
		Age in years					Age in years				
		4	4.5	5	5.5	6	8	8.5	9	9.5	10
Height	m	105.3	108.4	112.0	114.3	116.7	120.4	123.1	126.6	128.7	131
	sd	6.2	5.9	5.9	6.2	6.3	6.4	6.4	6.5	6.6	6.5
Weight	m	14.3	15.7	16.7	17.8	19.1	18.9	20.7	21.9	23.3	24.7
	sd	2.0	2.1	2.2	2.5	2.5	3.3	3.4	3.6	3.7	3.9
Endomorphy	m	2.6	2.4	2.4	2.4	2.5	2.2	2.1	2.2	2.4	2.4
	sd	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.6
Mesomorphy	m	3.6	3.3	3.7	3.5	3.8	2.8	2.6	3.1	2.7	3.3
	sd	0.9	0.6	0.7	0.8	0.6	0.8	0.7	0.8	0.8	0.7
Ectomorphy	m	3.3	3.2	3.5	3.5	3.5	4.6	4.4	4.6	4.5	4.5
	sd	1.5	1.3	1.1	1.1	1.1	1.2	1.0	1.0	1.0	1.0
SAMs	m	1.6	1.3	1.3	1.3	1.1	1.3	1.1	1.2	1.2	1.1
	sd	0.7	0.6	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.7

SAM= Somatotype attitudinal mean, m= mean, sd= standard deviation,

Table 3: Frequency (n) and percentage frequency (%) of somatotype categories of Ellisras preschool girls and primary school girls

	Pre-school girls (n=99)					Primary school girls (n=309)				
Age in years	**4.0**	**4.5**	**5.0**	**5.5**	**6.0**	**8.0**	**8.5**	**9.0**	**9.5**	**10.0**
Somatotype Category	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
1 Balanced endomorph	2 (2.0)		1 (1.0)		1 (1.0)	2 (0.6)		2 (0.6)	5 (1.6)	
2 Mesomorphic endomorph	3 (3.0)	2 (2.0)			1 (1.0)					2 (0.6)
3 Mesomorph-endomorph	18 (18.2)	7 (7.1)	5 (5.0)	6 (6.1)	1 (1.0)		2 (0.6)	2 (0.6)	7 (2.3)	4 (1.3)
4 Endomorphic mesomorph	4 (4.0)	10 (10.1)	6 (6.0)	6 (6.1)	11 (11.1)		2 (0.6)	3 (1.0)	1 (1.3)	2 (0.6)
5 Balanced mesomorph	13 (13.1)	13 (13.1)	16 (16.2)	16 (16.2)	13 (13.1)	9 (2.9)	3 (1.0)	9 (2.9)	10 (3.2)	17 (5.5)
6 Ectomorphic mesomorph	8 (8.1)	2 (2.0)	5 (5.0)	9 (9.1)	10 (10.1)	4 (1.3)	1 (0.3)	6 (1.9)	3 (1.0)	5 (1.6)
7 Mesomorph-ectomorph	17 (17.2)	27 (27.3)	32 (32.3)	27 (27.2)	37 (37.4)	49 (15.9)	53 (17.2)	71 (23.0)	50 (16.2)	77 (24.9)
8 Mesomorphic ectomorph	17 (17.2)	12 (12.1)	21 (21.2)	11 (11.1)	10 (10.1)	74 (23.9)	52 (16.8)	73 (23.6)	37 (12.0)	76 (24.6)
9 Balanced ectomorph	15 (15.2)	23 (23.2)	11 (11.1)	22 (22.2)	14 (14.1)	150 (48.5)	181 (58.6)	137 (44.3)	175 (56.6)	123 (39.8)
10 Endomorphic ectomorph	2 (2.0)	3 (3.0)	2 (2.0)	2 (2.0)	1 (1.0)	16 (5.2)	13 (4.2)	4 (1.3)	19 (6.1)	3 (1.0)
11 Endomorph-ectomorph						5 (1.6)	2 (0.6)	2 (2.6)	2 (0.6)	

Table 4: The F-ratios of SADs for repeated measurements of Ellisras pre-school and primary school girls

Age (years)	4	4.5	5	5.5		8.5	9	9.5	10
4					8				
4.5	37.2*				8.5	43.6*			
5	18.5*	0.0			9	10.2*	8.4*	1	
5.5	14.4*	0.2	0.4		9.5	17.6*	1.7	1.7	
6	36.0*	7.8*	10.9*	20.3*	10	33.6*	0.5	10.2*	6.7*

* indicate significant difference ($P < 0.05$)

Dispersion of somatotypes about their means and analysis by separate components

Somatoplots are two-dimensional projections of the three-component somatotype; hence it is likely that the true distance between somatotypes is distorted. Therefore, the distance between somatotypes was calculated using the three-dimensional somatotype attitudinal distance, which is a true distance in component units between any two somatotypes (Carter et al., 1983; Carter and Heath, 1990). Differences among somatotype components and attitudinal means for repeated measurements of Ellisras girls are given in Table 5. Among the pre-school girls, the SAM values ranged from 1.1 (age 6.0) to 1.6 (age 4.0). Corresponding mean values ranging from 1.1 (ages 8.5 and 10.0) to 1.3 (age 8.0) were noted for the primary school girls. When the SAM values were analysed, results indicated that the SAM of 1.6 for the 4.0 year-old girls was significantly more substantial than values obtained for the rest of the pre-school girls ($p < 0.05$). A similar pattern was observed for the primary school girls, in which the 8-year olds had the highest SAM. Among the pre-school girls, no significant differences were found in the endomorphic and ectomorphic components across the age groups. However, the 4.0, 5.0 and 6.0-year old girls were more mesomorphic than the other age categories. In the primary school group, a consistent pattern was found in which the ectomorphic component ratings were homogenous among the older children (9.0, 9.5 and 10.0 year olds).

Migratory Distance (MD)

When somatotypes are followed over time the distance and direction of their path can be quantified (Carter and Heath, 1990). Stability of individual somatotypes is best shown by the sum of the SADs between a sequence of somatotypes obtained over the period of two and a-half years (Hebbelinck et al., 1995). This is referred to as the migratory distance (MD) and is calculated in component units (Carter et al., 1983; Heath & Carter, 1990). The average MD was 6.4 for pre-school children and 6.0 for primary school girls. The most stable pre-school and primary school girl had an MD of 2.6 and 3.4 respectively while the least stable pre-school and primary school girls had an MD of 17.9 and 24.4, respectively.

Table 5: Differences among somatotype components and somatotype attitudinal means for repeated measurements of Ellisras rural girls. (Preschool (4 to 6 years, n=99) and primary school (8 to 10 years, n=309))#

Somatotype variables	Mean value (Age in years) Pre-school girls (n=99)					Primary school girls (n=309)				
Endomorph	2.4 (4.0)	2.4 (5.0)	2.4 (5.5)	2.5 (6.0)	2.6 (4.0)	2.1 (8.5)	2.2 (8.0)	2.2 (9.0)	2.4 (10.0)	2.4 (9.5)
Mesomorph	3.3 (4.5)	3.5. (5.5)	3.6 (4.0)	3.7 (5.0)	3.8 (6.0)	2.6 (8.5)	2.7 (9.5)	2.8 (8.0)	3.1 (9.0)	3.3 (10.0)
Ectomorph	3.2 (4.5)	3.3 (4.0)	3.5 (5.0)	3.5 (5.5)	3.5 (6.0)	4.4 (8.5)	4.5 (8.0)	4.5 (9.5)	4.6 (10.0)	4.6 (9.0)
SAM[a]	1.1 (6.0)	1.3 (5.0)	1.3 (5.5)	1.3 (4.5)	1.6 (4.0)	1.1 (8.5)	1.1 (10.0)	1.2 (9.5)	1.2 (9.0)	1.3 (8.0)

[a] SAMs = Somatotype attitudinal means
Values underlined are homogenous, but are significantly different ($p<0.05$) from those that are not underlined.

Table 6: Inter-age partial correlations in Ellisras rural girls for somatotype[c] components at each period of measurements with mesomorphy and ectomorphy held constant at the lowest value. (Preschool (4 to 6 years, n=99) and primary school (8 to 10 years, n=309))

	Age in years					Age in years			
	4	4.5	5	5.5		8	8.5	9	9.5
4.5	0.88* 0.53 0.85*				8.5	0.86* 0.67 0.73*			
5	0.87* 0.54 0.68	0.95*0.620.83*			9	0.83* 0.64 0.60	0.91* 0.62 0.77*		
5.5	0.83* 0.50 0.59	0.88*0.430.70*	0.91* 0.29 0.87*		9.5	0.77* 0.38 0.48	0.84* 0.47 0.66	0.91* 0.38 0.79*	
6	0.75* 0.52 0.35	0.86*0.450.41	0.86* 0.28 0.59	0.87* 0.63 0.68	10	0.75* 0.46 0.50	0.82* 0.53 0.62	0.88* 0.44 0.73*	0.90*0.610.88*

(* =r>0.70) [c]Values are presented as partial correlations for endomorphy, mesomorphy and ectomorphy for each age group.

Partial correlation

In order to assess the stability of each somatotype component, inter-age partial correlations were computed for each somatotype component, whilst others were held constant. These calculations were done for the various periods of measurement. In the endomorphy high partial correlations (r <0.70) were found among all the age groups of the pre-school (r= 0.75-0.95) and primary (r=0.75-0.91) school girls. The mesomorphy did not yield high partial correlation (r > 0.70) in either group of girls. A consistent pattern of substantial partial correlation coefficient was found for ectomorphy among the groups.

4. Discussions

Until now, information on stability of somatotype has been published on children in American, European and Asian countries. Little information is available on countries in Sub-Saharan Africa. The present study showed that mean somatotype shifts from mesomorph-ectomorph to balanced ectomorph for the pre-school girls as well as from mesomorphic ectomorph and mesomorph-ectomorph to balanced ectomorph in the primary school girls. The general tendency of girls progressing from endomorphy towards central somatotype as stated by Carter and Heath (1990) was not evident in this sample.

Although ethnic differences, type of study and methodological differences may affect comparisons with studies from other countries, the findings of this study are generally similar to those reported in cross-sectional studies in Africa. Girls in the present sample showed a similar pattern as reported cross-sectionally by Monyeki et al., (1994, 1999b) in that throughout the age groups, pre-school girls tend to be dominant in mesomorphy and ectomorphy but less preponderant in endomorphy, while primary school girls had high ectomorphy with low mesomorphy and endomorphy. When the same children were followed longitudinally they were categorised as either mesomorph-ectomorph, mesomorphic ectomorph or balanced ectomorph. They are different from 10-year old Nigerian girls (Toriola and Igbokwe, 1985) who were more endomorphic. Monyeki et al. (2000) substantiated the high prevalence of malnutrition in older Ellisras rural children. This probably accounts for the fluctuations in the somatotype components found in the present study. The mean somatotype of Ellisras rural girls differs from the Belgian girls who showed an increased dominance in both endomorphy and ectomorphy and a decrease in mesomorphy (Duquet, 1980; Hebbelinck et al., 1995). The Czechoslovakian infants decrease in ectomorphy from the ages of 3.5 to 6 years (Parizkova et al., 1984) showed a large increase in endomorphy and mesomorphy and a marked.

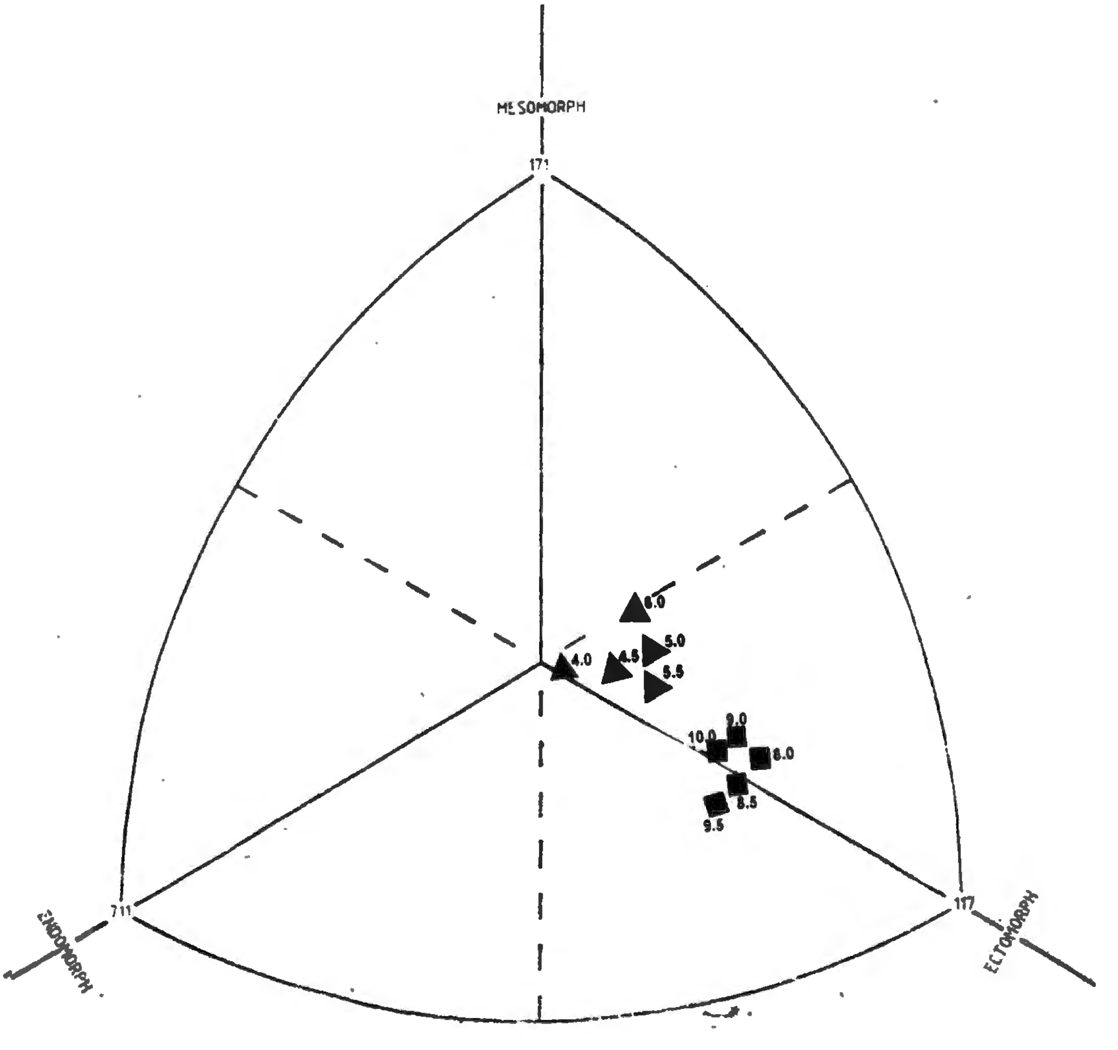

Figure1: Mean somatotype of Ellisras rural pre-school and primary school girls aged 4 to 10 years
▲ Pre-school girls (age 4 to 6 years)
▪ Primary school girls (age 8 to 10 years)

SAM measures the scatter of the somatotypes about the subjects' mean somatotype. A large SAM indicates a wide dispersion of the somatotypes over the three-year period. According to Carter et al. (1997), a SAM of 1.0 and more is large; 0.8-0.99, medium and of 0.79 and less, small. The larger SAMs at 4 years (mean=1.6; sd= 0.7) and at age 8 years (mean=1.3 sd 0.7) possibly reflect differences in timing of biological variations in growth and maturation within the sample, as it was reported by Malina and Bouchard (1991).

Stability largely depends on the initial measurement and the length of the period in most studies (Van Lenthe et al., 1996; Twisk et al., 1994). This is probably because the somatotype its less stable over a longer period (Carter & Heath, 1990; Hebbelinck et al., 1995). The inter-age partial correlations for endomorphy and ectomorphy were high and significant between adjacent and for mesomorphy the correlation were low and insignificant.

Examination of MD patterns over two and a-half years indicates that the somatotypes of individuals may show considerable change. MD values ranged from 2.6 to 24.4. This indicates that some pre-school girls vary up to 6.9 times and primary school girls 7.2 times more than others, although differences in MD of three or four times were common in both Parizkova and Carter (1976) and Hebbelinck et al. (1995) studies. However, their MD was calculated from primary school children up to about age 17 years. This probably accounts for the disparity between the present findings and results of the previous studies

Malina and Bouchard (1991) and Carter and Heath (1990) reported that some environmental factors like nutrition, exercise, health habits, disease and the timing of biological maturation, influence changes in physique. Even though Steyn et al. (1992) have shown that rural school children are provided with tow meals daily the energy intake is low. However, additional studies are needed to determine the role of genetics and environment in answering the question why some children's somatotypes are more stable than others, that is, whether a condition of hereditability of somatotype exists.

5. Conclusion

In general, based on the analysis and within the limitations of the study, the results of the Ellisras Longitudinal Study lead to the following conclusions:

The mean somatotype shifted from mesomorph-ectomorph to balanced ectomorph for pre-school girls and from mesomorphic ectomorph and mesomorph-ectomorph to balanced ectomorph in primary school girls.

There is considerable instability of individual somatotype compared with group changes. Small inter-age changes in mean somatotypes often mask large changes in individuals.

The inter-age partial correlations for endomorphy and ectomorphy are high and significant, but insignificant with regard to mesomorphy.

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Therefore !!!

8

GENERAL SUMMARY, DISCUSSION, CONCLUSION AND RECOMMENDATIONS

8.1 Introduction

Anthropometric indicators are most effectively used to assess the nutritional status of a population, as an expression of the magnitude and distribution of undernutrition (Gorstein & Akre, 1988). In terms of socio-economic, demographic and health indicators, the developing status of the rural South African population is apparent. Measuring nutritional status using anthropometric indicators is thus an important screening device to identify vulnerable groups.

In November 1996, a total of 1335 children (684 boys, 651 girls), 3 - 10 years of age, from rural villages situated within the north-western area of the Northern Province (approximately 70km from the provincial town of Ellisras 23° 40S 27° 44W adjacent to the Botswana border) of South Africa were anthropometrically evaluated in order to classify their nutritional status. Over the following two years (November 1996 to 1998) the children were evaluated both in May and November of each year and their growth status was recorded. The prevalence of chronic poor nutritional status (stunting-low height-for-age) (Cameron et al., 1998) ranged from 3.7% to 28.6% for boys and 3.5% to 41.8% for girls between the ages of 3 and 10 years. The prevalence of acute poor nutritional status (wasting-low weight-for-height) (Cameron et al., 1998) between the age of 3 and 10 years of age ranged from 25.9% to 54.6% and 21.4 to 44.8% for both boys and girls respectively. The tracking coefficient for malnutrition was high after two years. Somatotype analyses confirmed the poor nutritional status of this sample.

This chapter comprises a summary of the main findings and recommendations for health professionals on the five studies reported in this thesis.

8.2 Summary of the major findings

8.2.1 Growth of rural children

Ellisras rural black children exhibited a trend of diminished growth velocities prior to adolescence. Patterns of growth in height showed that these children grew parallel to the 50^{th} centile up to the age of six years and then both sexes demonstrated a gradual decline in height velocity, such that their mean heights diverged by approximately 0.5 cm per year. In both sexes weight increments were consistently between 1 and 2kg per year in contrast to the increments of the reference sample (NHANES III), which gradually increased to approximately 3kg per year by 10 years of age. The Ellisras rural environment for children was evidently not conducive to normal growth and, by implication, optimal health.

8.2.2 Prevalence of malnutrition and socio-economic status

Multiple aspects of physical and psychological factors influence the growth of children. In the present study it was decided to examine socio-economic status of the children in relation to their nutritional status. The following three different socio-economic groups based on the fathers' occupation (Lindren & Cernerud, 1992; Rona, 1981), were used in the study:

HIGH-GROUP I Professionals, high ranking civil servants and executives businessmen executives, tradesmen (e.g. electricians)

MODERATE-GROUP II Clerical works, salesmen, traditional healers, makers of handicrafts

LOW-GROUP III Labourers, cleaners, house helpers, shop assistants, drivers, vendors, subsistence farmers

Stunting ranged from 0 to 50%, 0% to 66.0% and 2.5 to 38.0% in the three categories of the socioeconomic status, respectively, between the age of 3 to 10 years. Wasting ranged from 0% to 41.0%, 10.0 to 26.1% and 5.9% to 43.1% in the three different socioeconomic status categories respectively, between age 3 to 10 years. However, the high level of stunting and wasting in each socioeconomic category was probably affected by the limited sample in each age group, since children were initially randomly selected according to their age group, and not by their parental occupation.

The patterns of rural growth as reflected by nutritional status, was similar in all three socioeconomic groups with no significant differences between the three groups. One possible explanation for this was the findings that even the higher income groups were still relatively low and all the participants shared the same environmental factors (Steyn & Walker, 2000).

8.2.3 Tracking malnutrition

Ellisras children generally experienced poor nutritional growth. Based on the tracking analyses, it appeared that poor nutritional status (growth) was relatively stable over a period of two years. It was shown that the poor nutritional status of the ELS children in comparison with the reference population did not improve but instead worsened with increasing age. Strong positive tracking coefficients were found in this sample. The tracking coefficient could be used as a predictor of future nutritional growth.

8.2.4 Stability of somatotyping

The mean somatotypes of ELS boys fluctuated from balanced ectomorphy to mesomorphic ectomorph and vice versa over a period of two years. Even though the somatotype of some ELS boys was stable it was evident from the migratory distances that unstable boys had changes up to two or more times greater than the most stable boys. The inter-age partial correlations for endomorphs and ectomorphs were high and significant, but low and insignificant in mesomorphs, which confirmed the poor nutritional status of the ELS boys as observed in earlier studies in this report.

The mean somatotype shifted from mesomorph ectomorph to balanced ectomorph in the pre-school girls (4 to 6 years) as well as from mesomorphic ectomorph and mesomorph-ectomorph to balanced ectomorph in the primary school girls (8 to 10 years). Examination of MD patterns over two years revealed that the somatotypes of individuals could show considerable change. MD values ranged from 2.6 to 24.4. This indicated that some pre-school girls varied up to 6.9 times and primary school girls up to 7.2 times more than other ELS girls. Even though inter-age partial correlations for mesomorphy were low, predictability of somatotypes in this study remained high. Somatotype analysis confirmed the poor nutritional status of these girls. The analyses of somatotype data in Ellisras rural area indicated that malnutrition escalated with increasing age.

8.3 General discussion and conclusions

The net results of the poor nutritional environment in which the Ellisras children live were an increasing prevalence of heights, weights and BMIs less than the reference standards (5^{th} centile) by 10 years of age. The prevalence of acute and chronic malnutrition in rural Ellisras children increased with increasing age, irrespective of the socio-economic status, of children in the sample. This was also shown by many of the subjects changing from balanced ectomorphy to mesomorphic ectomorph in the somatotype analyses. It may be that the progressively reduced increments during this period of growth reflect an adaptive mechanism and that "compensatory" adolescent growth may result in adult heights that are closer to the 50^{th} centile (Cameron et al., 1994). Although there is little evidence to suggest that, in the boys at least, mean weights will recover, since low BMIs are characteristic of African adult males (Eveleth and Tanner, 1991). Martorell et al. (1992) reported a loss of functional ability (physical work capacity) in young Gautemalan adults who had become stunted by the age of three years. It would appear that stunting in the current sample became most marked towards the end of childhood and the tracking analysis of the ELS sample suggests that this may be permanent. However, the implication that the long-term consequence of stunting in childhood is a loss of physical work capacity, is of real concern, and implies that the causes of poor growth amongst these rural children should be further investigated.

8.4 Recommendation for screening of nutritional intervention in rural South African populations

The anthropometric indicators for malnutrition selected for use in the ELS children are the most widely used in primary health care programs. WAZ, HAZ, WHZ and stability of somatotype, have also been used worldwide in growth monitoring and food-aid programs. These indicators have been found to be effective in predicting both chronic and acute malnutrition in children. Therefore, intervention to improve the nutritional status of rural South African children should be based on the use and interpretation of these indicators.

The high prevalence of wasting and stunting in this study are of major concern. It is recommended that the Department of Health should implement an effective surveillance system among school children in rural areas. Weight and height measurements should be given priority since scales and the Martin anthropometer are available at most health centers and weighing is done routinely for monitoring of pre-school children. In programs that do not use the above indicators, arm circumference could be used as an alternative (Ruel et al., 1996). The information obtained should be used to determine which children are vulnerable and consequently intervention program should be implemented, as quickly and effectively as possible.

The choice of cut-off points for screening children should be reconsidered. The usual –2 SDs below the median of the NCHS/NHANES standard, which have been used in the ELS study, showed that many children who are at risk due to false negative results and low sensitivity to the test, and are eligible for the intervention, have been left out.

8.5 Policy implications

A crucial issue that needs to be addressed in future studies of growth screening is the choice of appropriate cut-off points under different circumstances. The following recommendations for the selection of the cut-off points, should be considered:

- South Africa is multi-cultural and has many groups at risk of malnutrition, hence to decide on specific cut-off points for nutritional intervention the prevalence of malnutrition in a specific population needs to be identified before the intervention. For rural South African children the –1 SD should be used as a cut-off point.
- The availability of resources that will determine the proportion of children from a given population that can receive the intervention should also be addressed.

Healthy, active, well-nourished children are a fundamental pre-requisite for sustained economic development. Therefore, interventions to improve the nutritional status of rural South African children should be focussed on children. Screening should be done as early as possible in the life of rural South African children. The first year of life is a period of growth acceleration in height, thus energy and protein requirements per kilogram of body weight are high (Ruel et al., 1996; Cameron et al., 1998). Using the data from ELS study Monyeki et al. (1999) reported that children from the age of 3 years to 10 years were mostly affected by undernutrition and an absence of overweight was found. The first three years of life have been referred to as the window of opportunity (Beaton, 1993; Berti et al., 1998), because it is the period of greatest vulnerability but also of greatest potential for responsive intervention. In Ellisras rural children the effects of under-nutrition worsened as they grew older since no intervention was introduced.

In the light of these findings, it is recommended that future work dealing with growth and stunting in rural South African children and in other rural African countries should adopt a broader and more interactive approach to the problem. Specifically, it will be necessary to consider the entire spectrum of factors that lead to growth failure and prevention of catch-up growth and the effects with which poor growth are associated.

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O NO!!! ....

this looks much better !!!

ELLISRAS RURAL COMMUNITY ANTHROPOMETRIC PROJECT

SUBJECT:	DATE OF BIRTH:	GENDER:
SUBJECT NUMBER:	NAME OF THE SCHOOL / PRE-SCHOOL:	

NUMBER	EXAM DATE	TRICEPS L			BICEPS			SUBSCAPULAR			SUPRASPINALE			TRICEPS R			ABDOMINALE			FRONT THIGH			MEDIAL CALF			COMMENTS

ELLISRAS RURAL COMMUNITY ANTHROPOMETRIC PROJECT

			WIDTH MEASURMENTS						GIRTH MEASUREMENTS													HEIGHT MEASUREMENTS				
NUMBER	EXAMDATE	WEIGHT	BIACROMIAL	A-P CHEST	TRANSVERSE CHEST	BIILIOCRISTAL	HUMERUS	FEMUR	HEAD	NECK	ANKLE	CALF	THIGH	GLUTEAL	WAIST	CHEST	WRIST	FOREARM (MAX. REFLEX)	ARMGIRTH (FLEXED)	ARMGIRTH R	ARMGIRTH L	HEIGHT	SITTING HEIGHT	ARM SPAN	TROCHAN TERION	COMMENTS

ELLISRAS LONGITUNAL STUDY

Subject Number: [ ] [ ] [ ] [ ] [ ] [ ] Birth Date: DD MM YY [ ] [ ] [ ] [ ] [ ] [ ] Interview Date: DD MM YY [ ] [ ] [ ] [ ]

School name:________ School Number:________ Interviewer:________
Interviewer Code: ________

SOCIO-DEMOGRAPHIC QUESTIONNAIRE

(All information in this questionnaire is confidential)

Child's name:________ Gender: M____ F ____
Address:________ Religion: ________
Mother's language: ________

Tel. (H) Work:

Relation to the child: Mother ____ Father____ Grandparent ____ Siblings____ Uncle/Aunt____ Others____

Household composition

Name of household members	Age in (yrs)	Gender		Family relationship to the child		Does this person eat and sleep at home at least four days a week?	
		M	F	*Relationship	Code	Yes	No

*Relationships (use the child as a reference) Father=1, Mother=2, Siblings=3, Grand mother =4, Grand father=5, Grand grand mother=6, Grand grand father =7, Uncle=8, Cousin=9, Friend = 10, Others=11

1. Where did this child spent his/her first year of life:Nameof the town:________
Village:________
2. How long has this child been living in the current area of residence: Years ____ Months ____ Since born ____

3. Did you spend more than one year in any place other than the above mentioned during the last ten years? Please list. ________

4. Where did the grand mother/father spent here first years of life:________
5. Where did the grand mother/father live the next four years of his/her life i.e. 1-5 years:________
6. Did the grand mother spend more than one year in any place other than mentioned above during the last ten years? (Please list the names): ________

3. Marital status of mother (Tick one):

1	2	3	4	5	6	7	8
Unmarried	Married	Divorced	Separated	Widowed	Living Together	Traditional Marriage	Other Please Specify:

Tick one block only for every question:	Father	Mother	Sibling	Grandma	Grandpa	Aunt	Uncle	Cousin	Friend	Other
4. Who is mainly responsible for food preparation in the house	1	2	3	4	5	6	7	8	9	10
4. Who decides on what types of food are bought for the household?	1	2	3	4	5	6	7	8	9	10
4. Who is mainly responsible for feeding/serving the child?	1	2	3	4	5	6	7	8	9	10
4. Who is the head of this household?	1	2	3	4	5	6	7	8	9	10
4. Who decides how much is spent on food?	1	2	3	4	5	6	7	8	9	10

Now look at this child and tick one block only for every question.

4. Would you (fieldworker) consider this to be a healthy child?	1 Yes	2 No	If no, specify:
10. Is this child disabled?	1 Yes	2 No	If yes, specify:

Now decide on the following (considering the household where this child lives):

1. Type of dwelling: You can tick more than one Block if necessary	1 Brick, Concrete	2 Traditional Mud	3 Tin	4 Plank, Wood	5 Other Specify:
Number of people sleeping in the house for at least 4 nights per week?					
Number of rooms in house (excluding bathroom, toilet and kitchen, if separate):					
Number of people per living/sleeping room (Tick one)	1 0-2 persons	2 3-4 persons	3 More than 4		

15. Where do you get drinking water most of the time? **(Tick one)**	1	2	3	4	5
15.	Own Tap	Communal Tap	River, Dam	Borehole, Well	Other (Specify)
15: What type of toilet does this household have? (Tick one)	1	2	3	4	5
15.	Flush	Pit	Bucket, Pot	VIP	Other (Specify)

15. What fuel is used for cooking most of the time? **(You can tick more than one)**	1	2	3	4	5	6
15.	Electric	Gas	Paraffin	Wood/Coal	Sun	Open Fire

Tick one box only:

18. Does the child's home have a **working:** (i) Refrigerator/Freezer	1	2	3	4			
18.	Fridge	Freezer	Both	None			
(ii) Stove	1	2	If yes, choose one			If yes, choose one	
	Yes	No	Gas	Coal	Electricity	With Oven	Without Oven
(iii) Primus or Paraffin Stove	1	2					
	Yes	No					
(iv) Microwave	1	2					
	Yes	No					
(v) Hot Plate	1	2					
	Yes	No					
(vi) Radio or Television	1	2	3	4			
	Radio	TV	Both	None			

Now ask questions about:

19 Education level of mother (Tick one only)	1	2	3	4	5	6
18.	None	Primary School	Std 6-8	Std 9-10	Tertiary Education	Don't Know
20. Mother's employment status (Tick one only)	1	2	3	4	5	6
	Housewife By choice	Unemployed	Self-Employed	Wage-Earner	Other Specify	Don't Know
20. Education level of caregiver (Tick one only)	1	2	3	4	5	6
	None	Primary School	Std 6-8	Std 9-10	Tertiary Education	Not Applicable
20. Father's employment status (Can tick more than one)	1	2	3	4	5	6

	Unemployed	Self-Employed	Wage-Earner	Retired by Choice	Other Specify	Not Applicable e.g. dead
20. How many people contribute to the total income? (Tick one only)	1	2	3	4	5	
20.	1 person	2 persons	3-4	5-6	More than	

24. Household income per month (including wages, rent, sales of vegs, etc. State grants). (Tick one only)	1	2	3	4	5	6	7
24.	None	R100-R500	R500-R1000	R1000-R3000	R3000-R5000	Over R5000	Don' know

24. Is this the usual income of the Household? (Tick one box only)	1	2	If NO, what other income is available, specify:
24.	Yes	No	

24. Is this more or less the income that you had over the past six months? (Tick one only)	1	2
24.	Yes	No

27. How much money is spent on food weekly? (Tick one only)	1	2	3	4	5	6	7	8	9	10
24.	R0-R50	R50-R100	R100-R150	R150-R200	R200-R250	R250-R300	R300-R350	R350-R400	Over R400	Don't know

Thank you for reading this Thesis.