Micronutrient deficiencies in South African infants and the effect of a micronutrient-fortified complementary food on their nutritional status, growth and development

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Propositions

1. Information on body anthropometry alone is not sufficient to assess the nutritional status of infants *(this thesis).*

2. Ethnic groups from the same poor urban community may differ significantly in nutritional status *(this thesis).*

3. The cognitive development of an infant is a complex process influenced by multiple genetic and environmental factors that interact with one another. *Arch Dis Child 1994;71:376-380.*

4. In the real world there are many competing factors that affect mothers' decision on feeding and weaning. *Lancet 1999;353:327.*

5. The empowerment of women is of central importance to improve nutrition of both women themselves and their children. *The State of the World's Children, UNICEF, New York 1998.*

6. In developing countries complementary feeding practices remain inadequate in terms of timeliness, quality, quantity and safety.

7. To address malnutrition Africa needs more development aid than food aid.

8. The western Cape of South Africa is a loose federation of climates.

Propositions belonging to this thesis entitled " Micronutrient deficiencies in South African infants and the effect of a micronutrient-fortified complementary food on their nutritional status, growth and development".
André Oelofse

Wageningen, 6 November 2001

To my parents
To Izette, Alexander and Isabella

Abstract

Micronutrient deficiencies in South African infants and the effect of a micronutrient-fortified complementary food on their nutritional status, growth and development.

Ph.D. thesis by André Oelofse, Division of Human Nutrition and Epidemiology, Wageningen University, The Netherlands. November 6, 2001.

Consequences of micronutrient deficiencies in infants often include linear growth retardation, impaired psychomotor development and reduced appetite. Fortification of complementary food is one way of addressing micronutrient deficiencies in this age group. Knowledge about these deficiencies, food consumption patterns and appetite in infants is essential in planning micronutrient fortification intervention studies. In this thesis four studies are described, two of which studied the prevalence of micronutrient deficiency and linear growth retardation in rural and urban disadvantaged South African infants. The third study determined the adequacy of the appetite of infants at the age of 6 months. The final study is an intervention study with the aim to study the effect of a micronutrient fortified complementary food on the nutritional status, growth and development of 6-12-month-old poor urban infants.

The results from the first two studies showed a high prevalence of vitamin A, iron and zinc deficiency in both rural and urban infants. The low socio-economic status of the urban community and sub-optimal feeding practices may explain the similarity of deficiencies observed between rural and urban infants. The third study demonstrates that appetite was adequate in infants at the age of 6 months and not yet affected by micronutrient deficiencies. The consumption of a micronutrient-fortified complementary food appeared to reduce the decline in both serum retinol and iron concentrations in the experimental group. No effect was observed on serum zinc concentration, linear growth and psychomotor development.

In conclusion, the findings of this study demonstrate similar levels of nutritional deficiencies in both poor urban and rural children. Significant differences between urban disadvantaged coloured and black infants with respect to micronutrient deficiencies and linear growth exist. This highlights the importance of including assessment of micronutrient status in addition to anthropometric measurements when assessing nutritional status. The observation of an adequate appetite in infants at the age of 6 months is important for the introduction of micronutrient-fortified complementary food. The observed positive effect of a micronutrient-fortified complementary food on serum retinol and iron concentrations in 6-12-month-old infants should be investigated further.

Contents

1

General Introduction

The global importance of micronutrient deficiency has been illustrated through a variety of nutritional goals to be achieved by the year 2000 and formulated at the World Summit for Children (1990), The Policy Conference on Micronutrient Malnutrition: Ending Hidden Hunger (1991) and the International Conference on Nutrition (1992). These goals focussed on the nutrition and health of infants, young children and women and included the virtual elimination of vitamin A and iodine deficiency and the reduction of iron deficiency anaemia in women by one-third. It also aimed at halving severe and moderate under nutrition in children under 5 years of age.

Notwithstanding considerable advances towards achieving these goals, significant challenges remain in terms of research and implementation. Hence, the Preparatory Committee for the United Nations Special Session of the General Assembly on Children re-aligned some of these goals. It resolved to reduce the percentage of children with stunted growth under the age of 2 years by at least one third, to develop and implement national early childhood development policies and programmes to ensure the enhancement of children's physical, social, emotional and cognitive development. In addition it aims at the sustainable elimination of iodine deficiency disorders by 2005 and vitamin A deficiency disorders and anaemia, including iron deficiency anaemia, by 2010.

However, Scrimshaw and Gleason remarked that the statement with regard to iron deficiency was unrealistic and should be restated. The current aim is to reduce the prevalence of anaemia, including iron deficiency anaemia, in pregnant women and infants less than 2 years of age by at least one-third of the 2000 level by the year 2010 (Preparatory Committee for the Special Session of the General Assembly on Children; Scrimshaw *et al.*, 2001). These goals demonstrate political commitment in dealing with these issues. It also emphasises the caution and realism with which such goals should be set.

The serious nutritional deficiencies and its consequences existing in the developing world urged political and health leaders to set these goals. Marginal vitamin A deficiency affects 250 million preschool children. Iron deficiency anaemia, considered the most common nutritional deficiency, affects more than 2 billion people in these regions (Stoltzfus, 2001). Epidemiological data on zinc deficiency remains scarce, predominantly due to a lack of reliable indicators for zinc status, but is considered as important as iron deficiency (Hambridge, 1988; ACC/SCN, 2000).

The poor and underprivileged children in developing countries are at particular risk of these nutritional deficiencies. An adequate nutritional status is imperative for good physical and mental development of infants (Kikafunda *et al.*, 1998; Getaneh *et al.*, 1998; Vazir *et al.*, 1998). The serious growth and developmental consequences of micronutrient deficiencies in preschool children are well known. Children suffering from micronutrient deficiency often present with linear growth retardation, higher morbidity and mortality and reduced psychomotor development (Bhandari *et al.*, 1996; Pollit *et al.*, 1995; Grantham-McGregor *et al.*, 2001), thus preventing them to develop to their full potential. Most startling is the grave end-points of these deficiencies if left untreated. It kills, maims, retards, cripples, blinds and impairs human development on a massive scale.

An inadequate dietary intake is considered one of the major causes of micronutrient deficiency. The latter may be influenced by a variety of issues including a reduced appetite (Hadju *et al.*, 1996), lack of food availability and accessibility and parental feeding practices. Figure 1 gives a simplified conceptual framework of the potential causes and most important consequences of micronutrient deficiency in infants.

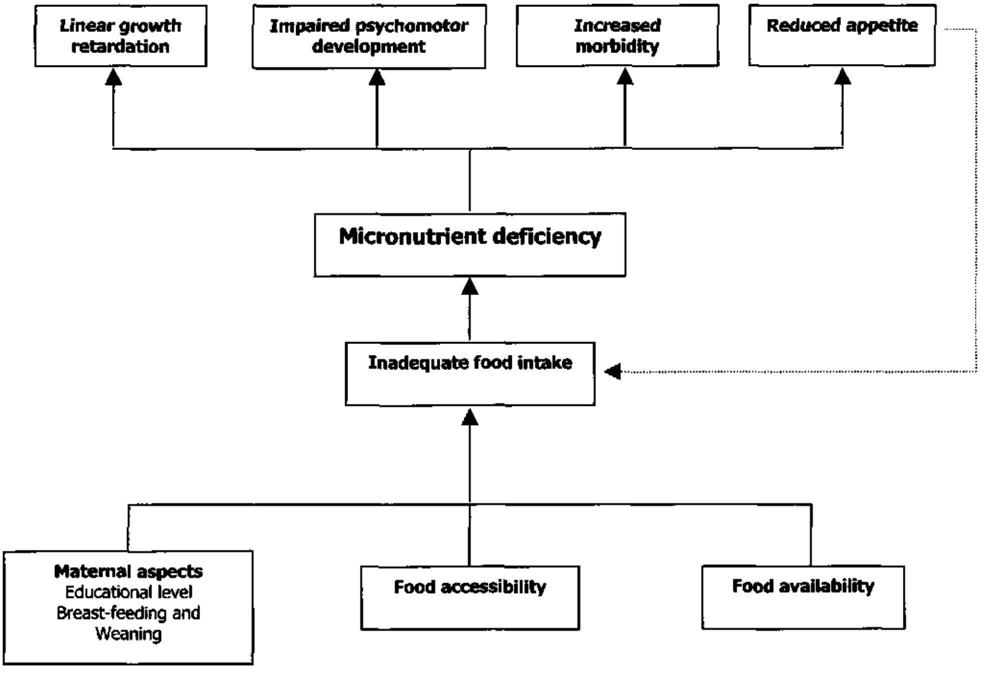

Figure 1 Simplified conceptual framework of causes and consequences of micronutrient deficiencies in preschool children.

In this chapter the focus will be on deficiencies of vitamin A, iron and zinc in preschool children, its detrimental consequences and potential causes. Ways of addressing micronutrient deficiencies in preschool children will be discussed. Finally, the situation with regard to micronutrient deficiency in South Africa will be presented.

Micronutrient deficiencies and its consequences

In the following paragraphs deficiencies in serum retinol, iron and zinc concentrations in preschool children will be presented. The consequences and possible causes of these deficiencies will be elaborated on.

Vitamin A deficiency

Of the estimated 125 million preschool children who are vitamin A deficient, approximately 1 to 2.5 million die annually as a consequence (ACC/SCN, 2000). Improving vitamin A status of young children can reduce the mortality rate by 23% in populations where vitamin A is deficient (Beaton *et al.,* 1993). This emphasises the importance to pursue effective ways of addressing vitamin A deficiency.

Vitamin A deficiency is determined by measuring serum retinol concentration in individuals and communities. Deficiency can be categorised into marginal (serum retinol <20 µg/dL) and severe vitamin A deficiency (serum retinol <10 µg/dL). Manifestations of severe vitamin A deficiency are defined by the presence of night blindness, Bitot's spots, corneal xerosis and xerophthalmia-related corneal scars. Although corneal disease is seldom seen before the age of 12 months, children in poor, transitional populations are increasingly at risk of developing keratomalacia. Marginal vitamin A deficiency is often associated with increased morbidity. Often infants of these populations are weaned at an early age. The subsequent early introduction of milk products or weaning food, often low in vitamin A or incorrectly prepared, may contribute to vitamin A deficiency (Underwood, 1993). Although often seen in many African countries, the clinical manifestations of vitamin A deficiency are rarely seen in South Africa.

Many studies have been conducted to establish an association between serum retinol, linear growth, morbidity and mortality. Although vitamin A supplementation produced higher serum retinol concentrations in an experimental group of low birth weight infants it did not reduce the prevalence or severity of respiratory infection (Coutsoudis *et al.,* 2000). However, supplementation with vitamin A reduced the incidence of measles morbidity in 4-24-month-old infants (Coutsoudis *et al.,* 1991). In a large observational study among 6-72-month-old Sudanese children, dietary vitamin A intake was associated with attained height and a reduced risk of stunting. However, these observations may not have been due to vitamin A *per se* (Fawzi *et al.,* 1997). An association between plasma retinol concentration, attained height and severe stunting was observed in a group of Bangladeshi preschoolers (Fuchs *et al.,* 1994). Conversely, in a cohort study among Zambian infants no association was observed between linear growth and serum retinol

(Hautvast *et al.,* 2000). In a group of 6-48-month-old Indonesian children high doses of vitamin A supplementation improved linear growth selectively. Age, initial vitamin A status and breast-feeding influenced the magnitude of the effect. Children with an initial serum retinol greater than 10 µg/dL showed no response to supplementation (Hadi, *et al.,* 2000).

Iron deficiency anaemia (IDA)

Iron deficiency leads to anaemia, originally defined as a haemoglobin (Hb) concentration of less than 11 µg/dL in young children (WHO, 1972). Iron deficiency affects approximately 2 billion people in the world. This makes it the most prevalent of the nutritional deficiencies. Iron deficiency has been associated with impaired psychomotor development and reduced physical activity in children. It also lowers immunity and adversely affects birth weight and mother and child survival. It impairs cognitive development in children. Productivity and educational impairments have been ascribed to iron deficiency anaemia (ACC/SCN, 2000).

Infants are particularly vulnerable to the depletion of iron stores because of their rapid growth during this phase. The benefit of either short of long term iron treatment on cognitive development remains inconclusive (Grantham-McGregor *et al.,* 2001). In a meta-analysis of iron studies short term iron treatment did not seem to benefit the cognitive development of anaemic children younger than 2 years of age. However, in older children it was found that anaemic children had poorer cognition and school performance compared to non-anaemic children (Grantham-McGregor *et al.,* 2001). A strong causal effect has been demonstrated between severe iron deficiency, moderate iron deficiency and aerobic capacity in both humans and animals. Evidence also exists of an association between IDA and a reduced aerobic capacity. Severe IDA and moderate IDA also impaired endurance capacity (Haas *et al.,* 2001). The latter may indirectly affect motor development in young children.

The most alarming of iron deficiency is the potential long term developmental and behavioural risk. A group of 11-14-year-old Costa Rican children who were iron deficient as infants, scored lower in mental and motor development tests compared to children who were not iron deficient (Lozoff *et al.,* 2000). Iron deficiency anaemia in children has also been associated with an increased risk of mild to moderate mental retardation in later life (Hurtado *et al.,* 1999). If one considers the number of children potentially affected, it could have tremendous implications for future individual and collective productivity in developing countries.

Zinc deficiency

Zinc deficiency in preschool children is defined as a plasma zinc concentration below 60 µg/dL. Zinc deficiency causes a reduction in immuno-competence, an increase in infectious disease morbidity and a reduction in growth and impairment of motor and cognitive development (Schlesinger *et al.,* 1992).

Many studies have reported the association between zinc deficiency and morbidity. Zinc deficient children between the ages of 12 and 59 months had substantially more episodes of diarrhoea when compared with children with normal zinc levels. In the same group, the incidence of acute lower respiratory tract infection (ALRI) was significantly higher in the zinc deficient children (Bahl *et al.,* 1998). In younger children (6-35 months) zinc supplementation substantially reduced the incidence of respiratory morbidity (Sazawal *et al.,* 1998). When supplementing low birth weight (LBW) infants with 5 mg of zinc daily a significant reduction in prevalence of both ALRI and diarrhoea was found (Lira *et al.,* 1998).

In a longitudinal study among Zambian infants no association was found between serum zinc concentration and linear growth (Hautvast *et al.,* 2000). Ruz *et al.* (1997) showed no significant benefit in linear growth in a zinc supplemented group of 27-50-month-old preschool children from a low socio-economic background. No effect of zinc supplementation on linear growth was found in Mexican children receiving either zinc or iron or zinc/iron supplements (Rosado *et al.,* 1997). In 4-36-months-old undernourished Vietnamese children daily supplementation with 10 mg of zinc positively increased both weight and height and reduced the incidence of diarrhoea and respiratory illness (Ninh *et al.,* 1996). Stunted Ethiopian infants had a greater increase in length compared to non-stunted and placebo infants after daily supplementation with 10 mg zinc. A marked reduction in morbidity was observed (Umeta *et al.,* 2000). Similar results were obtained in 1-6-month-old Bangladeshi infants. Improved growth and reduced ALRI was observed only in the stunted infants (Osendarp *et al.,* 2001).

Due to the structural and functional role of zinc in the brain, attention has been focussed on the possible involvement of zinc in psychomotor development (Hesse, 1979). Repletion of zinc through micronutrient supplementation improved neuro-psychological and growth performance (Sandstead *et al.,* 1998). Daily supplementation with 5 mg of zinc to low birth weight term infants resulted in higher Bailey test scores among the supplemented group compared to a placebo and a group receiving 1 mg of zinc (Ashworth *et al.,* 1998).

Plasma zinc concentration has been most commonly used to indicate zinc status and has been found adequate for this purpose at population level (Brown, 1998).

However, there are also limitations of plasma zinc concentration as indicator of zinc status. It can be influenced by infection as well as zinc intake. The most reliable indicator of a low zinc status remains the effect of zinc supplementation (Meeks *et al.,* 1998).

Linear growth retardation

One of the most obvious signs of chronic malnutrition is linear growth retardation. An estimated 33% of preschool children in developing regions are stunted. Of these 24 percent live in sub-Saharan Africa (WHO, 2000).

A child is considered stunted when the measured height for age of the child is below –2 standard deviations (SD) below the median of the National Center for Health Statistics (NCHS) reference height for age (Hamill *et al.,* 1979). The World Health Organization (WHO) created categories of stunting to indicate the level of severity of stunting on a population basis. A prevalence of stunting of <20% is considered low. Between 20% and 30% is considered medium and between 30% and 40% high, and a prevalence of stunting above and equal to 40% is considered very high. The question has often been raised whether it is appropriate to apply the NCHS reference data to different ethnic groups. However, Ulijaszek (1994) concluded that, although the NCHS reference has its limitations, all major population groupings have a similar growth potential. He argued that the observed differences could largely be ascribed to differences in nutritional status and environmental factors. Droomers *et al.,* (1995) supported this by observing Indonesian preschool children of high socio-economic class growing taller and heavier than the NCHS reference population.

Stunting is usually a sign of chronic nutritional deficiencies, with its origin at an earlier age, mostly from the age of 2-4 months. Its onset is generally associated with the age of the introduction of complementary feeding (Brown *et al.,* 1995). However, many children only appear stunted after 24–36 months of age whilst the onset may commence much earlier (Waterlow *et al.,* 1988). Thus, linear growth retardation develops in a relatively narrow age window. But once a child is growth retarded, stunting usually remains for life, with limited potential for catch-up growth. If linear growth retardation is not reversed or redressed at an early stage it could put children into a sub-optimal growth pattern for future growth. This emphasises the importance of addressing linear growth retardation at the earliest possible age when nutritional deficiencies occur. Apart from chronic micronutrient deficiencies, low birth weight could also contribute towards short stature (Binkin *et al.,* 1988).

A high prevalence of stunting is often associated with poor socio–economic conditions (Gorstein *et al.,* 1994). Stunting is associated with other detrimental consequences of nutritional deficiencies including impaired psychomotor development. These children are also usually at a higher risk of morbidity and often have impaired immune function (Pelletier, 1994; Chandra *et al.,* 1991).

Although stunting is common in South Africa, the prevalence of stunting is generally not as high as that of some of the neighbouring countries. For example, in Mozambique, Zambia and Lesotho the prevalence of stunting varies from 36% to 44% (WHO, 2000).

Impaired psychomotor development

Children suffering from stunting as a consequence of micronutrient deficiencies often suffered from impaired psychomotor development (Grantham-McGregor *et al.,* 1996). A more serious consequence is the long-term deficits in mental performance. Even if growth-restricted children received psychosocial stimulation, the benefit is small (Grantham-McGregor, 1991; Grantham-McGregor *et al.,* 2000; Walker *et al.,* 2000). A recent meta-analysis demonstrated a higher cognitive developmental score in breast-fed infants compared to formula-fed infants. This may suggest that breast-feeding may be nutritionally superior to formula-feeding. However, the study of cognitive development of infants is complex. It is influenced by multiple environmental and genetic factors thus benefiting the child's psychomotor development (Anderson *et al.,* 1999). Most factors associated with a reduced psychomotor development are also associated with poverty. To establish causality would be difficult and should include long term follow up studies (Grantham-McGregor *et al.,* 2001).

Causes of micronutrient deficiency

Inadequate food intake

Food availability, accessibility and food choices and habits play a crucial role in food intake (Figure 1). Forced, limited food choices through lack of availability, accessibility and often nutritional knowledge result in a diet often characterised by sufficient quantity but poor quality (Faber *et al.,* 1997). Poor infant feeding practices may contribute greatly to deficiencies seen in these children, even if availability and accessibility of food is sufficient (Gulden *et al.,* 2000). Poor socio-economic circumstances often co-exist with low maternal education. Both are believed to cause poor feeding practices. According to the United Nations Children's Fund (UNICEF), the most important contributing factors related to the trend towards increasing undernutrition in sub-Saharan Africa were decline in women's status, slow progress in improving women's educational status and low per capita food availability (Smith *et al.,* 2000).

Breast-feeding plays a crucial role in infant nutrition and should provide a complete source of nutrition during the first 6 months of life (WHO, 1998). A study increasing protein intake together with breast-feeding concluded that there was no difference in weight gain or linear growth between an exclusively breast-fed group and a group receiving 20% additional protein (Dewey *et al.,* 1996). A study in south India clearly demonstrated that breast-fed infants met 90% of their daily vitamin A requirements compared to 60% in non-breast-fed infants (Ramakrishnan *et al.,* 1999). A recent review by a WHO expert committee concluded that exclusive breast-feeding is recommended to the age of 6 months. However, the review points out that exclusive breast-feeding could lead to iron deficiency in vulnerable groups. In addition, sufficient data does not yet exist to exclude potential risks including impaired linear growth retardation. However, the benefits of exclusive breast-feeding are considered to outweigh the risks (WHO, 2001). Beyond 6 months of age, breast-feeding does not meet the nutritional requirements of infants (WHO, 1998). It is in the age group of 6 – 12 months that nutritional deficiencies often develop. The reduction in breast-feeding and subsequent introduction of complementary food in this age group often result in micronutrient deficiency. Results from a study among healthy Swedish infants followed from birth to 12 months of age showed deficiencies in both iron and zinc. The use of fortified infant complementary food may have limited the bio-availability of iron and zinc from breast milk in these infants (Persson *et al.,* 1998).

Appetite

Although insufficient food availability, accessibility and inadequate parental feeding practices have been implicated in malnutrition, some studies failed to find an association between poor nutrition and food availability or poor parental feeding practices. Poor appetite, rather than the lack of food or poor feeding practises may be a more important determinant of inadequate food intake and partially explain inadequate food intake. A reduced intake of miconutrients or the presence of fever, diarrhoea and respiratory illness can cause poor appetite (Umeta *et al.,* 2000; Brown *et al.,* 1995). Poor appetite in infants from 3 to 12 months old could be related to low early weight gain and subsequent undernutrition, initiating a vicious circle (Piwoz *et al.,* 1994). Thus the restoration of appetite may play an important role in the prevention or treatment of nutritional and health problems of young children in developing countries (Engle *et al.,* 1996). Studies focus increasingly on the methodology of measuring appetite (Dossa *et al.,* 2001). Measurement of appetite in preschool children is of particular interest due to the serious long-term consequences of an inadequate food intake.

Addressing micronutrient deficiencies

Three of the major avenues for addressing micronutrient deficiencies most relevant to this thesis are food fortification, supplementation and dietary diversification. Food supplementation addresses both acute and chronic micronutrient deficiencies. It often needs infrastructure to be in place to ensure effectiveness. Dietary diversification primarily aims at a long-term approach to address chronic micronutrient deficiencies. Many countries work at the improvement of dietary diversification through home gardens and agricultural support. Food fortification is an important avenue through which to address nutritional deficiencies in preschool children.

Fortification with single or multi-micronutrients of the diet in young children has been proven successful in redressing linear growth retardation and morbidity (Sazawal *et al.,* 1998; Williams *et al.,* 1999; Umeta *et al.,* 2000).

Food fortification is the approach often sought by developing countries to address micronutrient deficiencies. This option also bypasses the lack of health infrastructure needed to deliver supplementation. The results of the South African national food consumption survey identified the most commonly eaten foods among children in this country. According to this survey maize, white sugar, tea, whole milk and brown bread were foods most commonly eaten by children aged 1-9 years (Labadarios, 2001). Therefore these foods seem the most appropriate vehicles for fortification. The report recommended that vitamin A, iron and zinc should be included in a national fortification programme. The recommended level of fortification was 33% of the recommended dietary allowance (RDA) at the point of consumption. This should curtail losses anticipated during food preparation, transport and storage. However, the report does not describe typical food consumption patterns of children less than 12 months, on whom few studies have been done. The report assumed that these children are predominantly breast-fed. Results from two studies among urban black South African children aged 6-24 months reported on the common consumption of commercially manufactured infant cereal (Faber *et al.,* 1997; Oelofse *et al.,* this thesis). These cereals are usually fortified with a variety of micronutrients.

The potential interaction between various micronutrients should be considered when fortifying food. Zinc plays a role in the synthesis of retinol binding protein involved in releasing vitamin A from the liver and increasing the absorption of retinol. Vitamin A also promotes the synthesis of a zinc- dependant binding protein and thereby the absorption and lymphatic transport of zinc (Christian *et al.,* 1998).

Vitamin A deficient individuals may develop anaemia despite adequate iron intake, as shown in randomised controlled trials of vitamin A supplementation (Hodges *et al.,* 1978). In such instances anaemia responds to vitamin A supplementation (Mejia *et al.,* 1982; Muhilal *et al.,* 1988). Combined supplementation with iron and vitamin A was more effective than either intervention used alone (Panth *et al.,* 1990; Garcia-Casal, 1998).

Iron and zinc compete in binding to plasma transferrin. This effect is less pronounced if an individual is deficient in either of these nutrients. It is also less if the nutrients are given as food compared to when they are given as supplements. Excessive iron intake can inhibit the absorption of zinc. However, when taken as a meal this inhibitory effect is less pronounced (Sandstrom *et al.,* 1985).

Few fortification studies have been done on infants. The recent report by Lartey *et al.* (1999) on Ghanian infants is an example of a fortification study using a centrally processed complementary food. In this study there was no observed effect in weight gain, length gain, iron status or plasma zinc concentration between infants aged 6-12 months. However, fortification with added micronutrients did result in significantly increased serum retinol concentration. The reduction in serum ferritin concentration was also significantly less in the micronutrient group (Lartey *et al.,* 1999). Williams *et al.,* (1999) demonstrated a reduction in psychomotor decline in infants consuming a commercial iron fortified milk compared to infants consuming unmodified cow's milk.

In summary, the positive health effects of improved dietary intake of micronutrients are clear. Efficacy studies in 14 countries demonstrated improved height for age z-scores (HAZ) in children by 0.1-0.5 SD, which might indicate that the effect on prevalence of stunting may be reduced by 1 - 19% in children aged 12 months. These studies also show that the greatest effect on growth is within the first year of life (Lutter *et al.,* 1990; Schroeder *et al.,* 1995). Stunting is associated with marginal deficiencies of several micronutrients. In these populations supplementation with a single micronutrient may not be sufficient to have significant effects on linear growth.

Extent of micronutrient deficiency in South Africa

Two large national and a few smaller studies have confirmed the occurrence of micronutrient deficiencies in South Africa (SAVACG, 1996; Labadarios, 1999). According to these studies marginal vitamin A deficiency (serum retinol <20 µg/dL) occurs in 33% of children. Rural children and children of mothers with a low educational level were most affected. Anaemia (Hb <11 g/dL) was present in 20% of children. It was found that anaemia and poor iron status were more prevalent in the urban areas and in children between the ages of 6 and 24 months in both rural and urban areas. Vitamin A deficient children were also more likely to be iron deficient. Stunting occurred in 25% of children with ten percent under-weight. This would indicate that 1.5 million children are malnourished. Throughout the country the prevalence of stunting was highest in the 12-23-month-old age group, but the severity of stunting varied between geographical areas. Children from rural areas had higher levels of stunting when compared to their urban counterparts. The type of housing and level of education of the mother were associated with stunting. Children living in informal urban or traditional rural African housing had higher levels of stunting (SAVACG, 1996; Labadarios, 1999).

Food intake is one of the most important factors in the etiology of malnutrition and stunting. In a national food consumption survey among 3120 children aged 1-9 years, it was found that the majority of children consumed a diet deficient in energy and with an insufficient micronutrient density to meet their requirements. In this study, rural children were worse off than urban children. Food insecurity, whether due to food accessibility or availability, was directly related to an inadequate dietary intake and increased levels of stunting and underweight. Most of the important micronutrients were consumed at less than 67% of the RDA. This included vitamin A, iron and zinc.

The South African government committed itself to reduce infant and under-5 mortality by one third to 50 and 70 per 1000 live births between 1995 and 2000. In addition it aims to reduce moderate and severe malnutrition among preschoolers by half (Steyn *et al.,* 2000). The goals for reducing infant and child mortality rates were achieved by 1999. The mortality of infants and children under 5 for that year were 47 and 66 per 1000 live births (SA Health Review, 1999). Although these achievements are a great step forward, the goals for reduction in malnutrition have not been met. However, these figures are much lower than other African countries e.g. Nigeria which has an infant and under-five mortality of 73 and 106/1000 live births respectively.

There are few detailed reports on the nutritional health status of infants from different ethnic groups or from various disadvantaged communities in South Africa. Such information is vital in order to plan community nutrition intervention programmes.

Objectives of this thesis

It is clear from the information above that micronutrient deficiency, specifically vitamin A, iron and zinc, have serious consequences for child growth and development. It is also clear that South African children are not yet as affected as neighbouring African countries. However, deficiencies may exist among infants, which may manifest after the age of 12 months as linear growth retardation, increased morbidity, reduced appetite and impaired psychomotor development. The prevalence may also differ between rural and urban communities. With increasing urbanisation it is necessary to effectively target efforts to prevent micronutrient deficiencies in infants. It is important to investigate ways of addressing these deficiencies effectively to prevent the grave consequences of malnutrition and to prevent the development of similar proportions as in other African and developing countries. The results of this study may assist governmental initiatives on food fortification to address malnutrition.

The overall aim of this study was to find ways of preventing micronutrient deficiency and linear growth retardation. To address this aim the following objectives had to be met. The extent of micronutrient deficiency and linear growth retardation in infants and preschool children in two typically rural and urban communities in two different geographical areas of the country had to be determined. Secondly, the adequacy of the appetite in urban infants at the age of 6 months had to be assessed. Finally an intervention study aimed at studying the effect of a micronutrient fortified complementary food on micronutrient status, linear growth and psychomotor development in 6-12 month old disadvantaged urban South African infants had to be conducted.

Study area

The study areas included one rural and two urban communities (Figure 2). The rural community (Ndunakazi) is about 60 km north-west of the capital of KwaZulu-Natal, Durban. The community is situated in a mountainous area. Two urban communities (Kayamandi and Cloetesville) close to Cape Town in the Western Cape were included in the urban study.

Ndunakazi comprises approximately 400-600 households scattered over a vast area. Families live in clay huts, water is collected from the nearby river, and sanitation facilities do not exist and the use of pit latrines and the veld is common. Most heads of households are women. During the week the majority of men work in the neighbouring industries. Women attend to small patches of land cultivating predominantly maize and attend to live stock. The community has a highly organised hierarchical structure with a chief in charge. In addition a women's league exists focussing on women and child health issues.

Kayamandi, in the Western Cape, is an urban community of approximately 14,000 inhabitants forming part of the greater Cape Town city. The majority of the inhabitants are black. Kayamandi is an example of a typical disadvantaged urban South African community. It consists of predominantly informal housing built in very close proximity to each other. Communal taps shared by households comprise the only water supply for the majority of households. Sanitation is in the form of communal toilets, but are often not functional. The community has one public health clinic for general, antenatal and infant care.

Migration to and from the rural areas is common. Perceived better health care in the cities draws mothers to these areas for ante- and postnatal care. Men flock to the urban areas to seek work. Women often follow, staying for varying periods of time. These migration patterns pose great operational challenges for longitudinal studies.

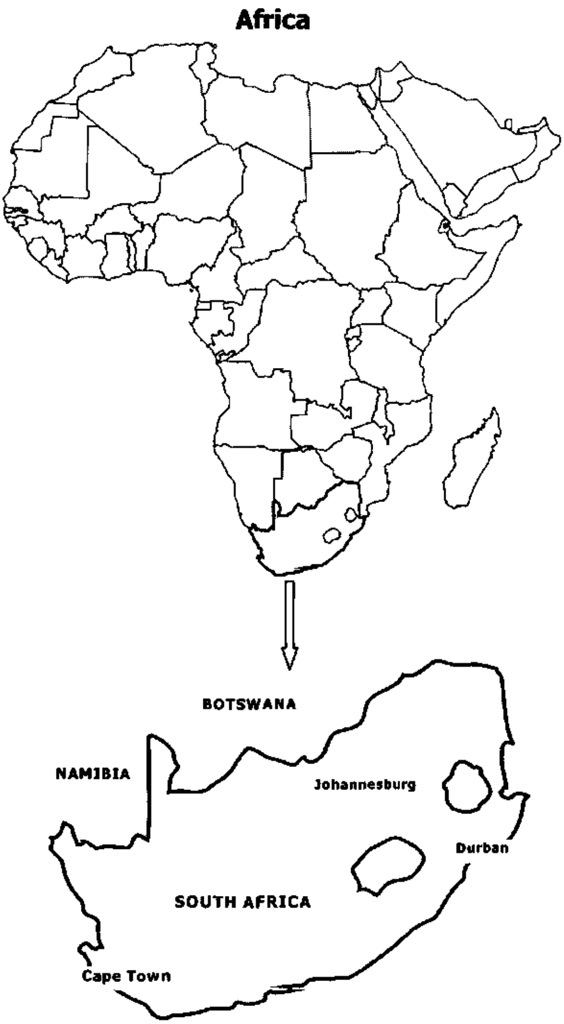

Figure 2. Location of South Africa within Africa and of study areas within South Africa

Cloetesville is a so-called coloured community located adjacent to Kayamandi. A single road separates the two communities. The community has 12,000 inhabitants and is served by one public health clinic. The houses in Cloetesville are predominantly brick houses, many of which are old and small. However, water supply and sanitation exists for every household. A small percentage of houses are informal. Some people also rent informal housing on the property of formal houses. Most families in Cloetesville have lived in the community for many years. The majority of them work in the city.

Outline of the thesis

Chapter 2 describes the micronutrient status and linear growth of pre- and primary school children in a rural community in KwaZulu Natal, South Africa. In *Chapter 3* the study reports on the nutritional status of 6-12 months old disadvantaged infants living in two urban communities in the western Cape, South Africa. These communities belong to two different ethnic groups, black and coloured. We compared the nutritional status of these communities using both anthropometric and biochemical indicators of nutritional status. In *Chapter 4* the adequacy of the appetite of urban disadvantaged infants at the age of 6 months was assessed since little quantitative information exists on energy intake of young children during the period of complementary feeding. *Chapter 5* reports on an intervention study. In this study the effect of a micronutrient fortified complementary food on the micronutrient status, linear growth and psychomotor development of 6-12-month-old disadvantaged urban South African infants was studied. Finally, in *Chapter 6*, the most important findings and consequences of the thesis are discussed.

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2

The nutritional status of a rural community in KwaZulu-Natal, South Africa: the Ndunakazi project

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Abstract

Objectives: To assess the nutritional status of 6 month to 11 year old rural black children and their mothers as a first phase in a nutrition intervention project.
Design: Cross-sectional study.
Setting: A rural African community ±60 km north-west of Durban, KwaZulu-Natal, South Africa.
Subjects: A random sample of 127 mothers and 105 preschool and 131 primary school children were selected from this community.
Results: The diet of these children lacked in variety and iron- and β-carotene-rich foods. In the absence of a severe or even moderate prevalence of growth retardation, serious micronutrient deficiencies were present in pre- and primary school children and their mothers in this community. Among the preschoolers anaemia was present in 24%, iron deficiency in 20%, while marginal vitamin A deficiency was observed in 45%. Urinary iodine levels indicated moderate iodine deficiency in 32% and severe iodine deficiency in 9%. In primary school children the prevalence of anaemia was 22%, while marginal vitamin A deficiency was observed in 51%. Moderate iodine deficiency was observed in 38% of primary school children while 14% presented with severe iodine deficiency. The prevalence of goitre in this group was 22%. Almost 22% of mothers were anaemic and 19% were iron deficient. Only 2% of mothers were marginally vitamin A deficient. An enlarged thyroid was observed in 27% of mothers of which 17% were palpable and 9% visible. Of mothers 43% were overweight while 34% were obese.
Conclusions: Although many positive socio-political changes have taken place over the past few years, undernutrition seems to prevail in many communities throughout the country. This rural community in KwaZulu-Natal was no exception, showing a high prevalence of anaemia, marginal vitamin A deficiency and iodine deficiency. The information gathered during this cross-sectional study served as a basis to plan and implement an intervention study aimed at addressing the nutritional deficiencies.

Introduction

It is well known that micronutrient deficiencies dramatically affect the overall health, child survival, productivity and mental performance of those affected (Pollit, 1995; Grantham-McGregor *et al.,* 1996; Sommer, 1990). The global proportions of these deficiencies and their effect on the quality of life of individuals necessitated action. It was at the World Summit for Children held in New York in September 1990 that world leaders committed themselves to address these micronutrient deficiencies. They did this by endorsing the Declaration for Children which has as some of its goals the virtual elimination of vitamin A and iodine deficiency. It also aims at reducing the number of mothers affected by iron deficiency anaemia by one third. Many effective methods exist to reduce these deficiencies, some of which have been most successfully applied in different countries (Sommer *et al.,* 1986; West *et al.,* 1997). It is within this framework that South Africa has to research and find ways of addressing nutritional deficiencies present among its own children. This study was part of the National Research Programme for Nutritional Intervention of the South African Medical Research Council's commitment to address the country's nutritional problems through sound scientific research. The aim of this study was to assess the nutritional status of mothers, preschool and primary school children from a rural community to serve as a basis from which to develop an intervention model to address the nutritional problems of this rural community. The study was ethically approved by the Ethics Committee of the Medical Research Council (MRC).

Methods

Study population and design

A rural community, Ndunakazi in KwaZulu-Natal, South Africa, was used as a study population. Ndunakazi is a deep rural, mountainous region making access to larger shops and clinic facilities difficult. At the time of the study no easily accessible clinic facilities were available on a regular basis within this community. As part of the nutritional assessment, anthropometric, socio-demographic and health information was collected from all accessible households (n=493). From this number a 25% random sample was drawn for blood collection purposes. One hundred and twenty seven mothers and their children comprising of 105 preschoolers from the age of 6 months to 5.99 years and 131 primary school children from 6 to 11 years old were studied. For the dietary information, a random sample of 87 (±1/3) children (27 preschool and 60 primary school) was taken from the initial sample of children from whom blood was drawn.

Dietary data

Dietary data was collected by questionnaire. Dietary practices were collected by a non-quantified dietary frequency method. Foods most commonly consumed were recorded with options to note frequency of consumption. To obtain this information from preschoolers their mothers were interviewed. In the case of primary school children both the child and the mother were present at the interview. Apart from the dietary information a few general questions were asked on matters concerning food availability and consumption patterns.

Anthropometry

Anthropometric measurements of weight and height of children and their mothers were taken without shoes and in light clothing as described by Jeliffe *et al.,* (1989). Weight was measured to the nearest 50 g on a calibrated electronic load cell digital scale (UC-300 Precision health scale). Length of children under 2 years was measured in a recumbent position on a baby board to the nearest 0.1 cm. The height of mothers and children older than 2 years was measured to the nearest 0.1 cm using a stadiometer attached to a wall. For the mothers body mass index (BMI) categories, as defined by Bray (1978), were used as an indicator of maternal nutritional status. For the children, anthropometric indicators, including the Z-scores for weight-for-height (WHZ), weight-for-age (WAZ) and height-for-age (HAZ), were calculated using the Epi Info version 6 software program (Dean *et al.,* 1993). The prevalence of underweight, stunting and wasting was defined as the percentage of individuals who had a WAZ, HAZ and WHZ score below -2 SD of the National Centre for Health Statistics (NCHS) reference median respectively (Gorstein *et al.,* 1994). The prevalence of underweight, stunting and wasting was categorised as low, moderate, high or very high according to World Health Organization (WHO) categories (De Onis *et al.,* 1993).

Laboratory analyses

Blood samples (5 ml from children and 10 ml from mothers) were obtained by venepuncture. Whole blood was analysed on a Coulter® Counter for haemoglobin values. Both red blood cell folate and serum ferritin concentrations were determined immuno-radiometrically. Plasma retinol was determined using a slightly modified version of the reversed-phase HPLC method described by Catignani and Bieri, 1983.

Clinical data

A medical doctor examined both mothers and children by palpation for the presence of an enlarged thyroid. Thyroid size was classified according to WHO recommendations as not palpable or visible (grade 0), palpable but not visible (grade 1) and visible (grade 2) (WHO, 1993). Urinary iodine was measured spectrophotometrically by means of the Sandaell-Kolthoff method (Dunn *et al.,* 1993). Urinary iodine levels (in µg/dL) were categorised according to the severity of iodine deficiency viz. mild (5.0-9.9), moderate (2.0-4.9) and severe (<2) (WHO, 1993). In addition to thyroid palpation, physical examinations were done to look for clinical signs of vitamin A deficiency and iron deficiency anaemia.

Parasitology

The prevalence of parasitic infection in children was determined by collecting a stool sample from each child. Consistency of stool was recorded and weighed sub-samples, usually between 0.5 and 1 g, was immediately mixed in 10% formalin. In the laboratory each sample was filtered and concentrated by centrifugation (formal-ether method). Geo-helminth eggs in the sediment were identified and counted by light microscopy (Evans *et al.,* 1997).

Results

Socio-demographic information

The unemployment rate was 33%. Most (80%) of the mothers had less than 7 years of schooling while 49% had less than 4 years. Nearly all mothers indicated that they obtained some food from home gardens, although limited, in addition to the food that they bought from the shop. The majority of mothers (83%) obtained water for domestic use from the local river. Of mothers interviewed 55% had 4 or more children. Thirty two percent of mothers lost a child before the age of 5. Of these 116 children 64% died before the age of 12 months. Although 50% did not know the cause of death, of the remaining, 67% indicated diarrhoea to be the cause of death.

Anthropometry

The prevalence of underweight, stunting and wasting together with the mean Z-scores for weight-for-Age (WAZ), height-for-age (HAZ) and weight-for-height (WHZ) for this population are shown in Table 1. The overall prevalence of underweight was low. However, although not significant, the prevalence of underweight doubled in the 12-23 month age group (4% to 8%). After the age of 24 months the prevalence was considerably lower at 3% in the 6-11-year-old children.

Table 1. *Prevalence of underweight, stunting and wasting in pre- and primary school children.*

Age group (months)	n	under-weight %	WAZ (SD)	Stunting %	HAZ (SD)	Wasting %	WHZ (SD)
6 – 11	47	4	0.18(1.25)	11	-0.45(1.35)	0	0.76(1.37)
12 – 23	96	8	-0.15(1.18)	20	-0.84(1.18)	4	0.49(1.49)
24 – 59	267	4	-0.04(1.24)	17	-0.50(1.73)	2	0.43(1.02)
60 – 132	336	3	-0.39(0.98)	20	-1.01(1.23)	1	0.51(1.07)

The prevalence of stunting doubled from the 6-11 month to the 12-23 month age group. Thereafter the prevalence of stunting remained fairly constant. Only in the 12 to 23-month-old age group was wasting of concern (4%). Forty-three percent of mothers were overweight while 34% were classified as obese.

Table 2: *Dietary intake of preschool and primary school children (%)*

	Every day	Most days	Once a week	Seldom	Never
Dairy Products					
Milk	1.2	10.3	10.3	65.5	12.6
Amasi	0	5.7	5.7	85.1	3.5
Yoghurt	0	0	4.6	64.4	31.0
Cheese	0	0	1.2	53.5	45.3
Animal Products					
Meat	0	24.1	26.4	42.5	6.9
Stew	2.3	33.3	16.1	42.5	5.7
Liver	0	2.3	1.2	64.4	32.2
Chicken	1.2	21.8	32.2	44.8	0
Fish, fresh	0	8.0	16.1	57.5	18.4
Eggs	8.1	21.8	16.1	54.0	0
Staple foods					
White bread	18.4	30.0	12.6	31.0	8.0
Brown bread	21.8	25.3	10.3	31.0	11.5
Maize meal porridge	55.2	17.2	21.8	4.6	1.2
Rice	4.7	41.9	3.5	20.9	29.1
Mixed dishes					
Samp and beans	0	48.2	40.7	7.4	3.7
Rice and beans	38.4	31.4	20.9	4.6	4.6
Maize and beans	1.2	9.2	16.1	63.2	10.3
Vegetables					
Cabbage	4.7	55.3	24.7	14.1	1.2
Carrots	0	3.5	5.8	72.1	18.6
Green beans	0	1.2	0	69.8	29.1
Imifino	17.6	62.3	17.6	2.4	0
Maize	3.5	3.5	12.9	80.0	0
Peas	0	0	0	65.9	34.1
Potatoes	58.1	39.5	0	2.3	0
Pumpkin	2.4	7.1	33.3	55.9	1.2
Spinach	0	14.1	20.0	64.7	1.2
Sweet potato	0	2.3	12.8	83.7	1.2
Tomato	66.3	32.5	1.2	0	0
Fruit					
Apple	2.3	27.6	13.8	56.3	0
Banana	2.3	18.4	19.5	59.8	0
Grapes	0	1.1	6.9	89.7	2.3
Guava	0	0	1.1	92.0	6.9
Peach	0	4.6	22.1	73.3	0
Pear	2.3	18.4	17.2	62.1	0
Orange	5.8	28.7	11.5	54.0	0
Fruit juice	1.2	5.8	18.6	65.1	9.3
Other food					
Soup	0	27.6	34.5	31.0	6.9
Biscuits	2.3	30.2	24.4	40.7	2.3
Sweets	2.3	26.4	12.6	55.2	3.5
Potato crisps	1.2	30.0	6.9	60.9	1.2
Niknaks	2.3	28.7	6.9	60.9	1.2
Cheese curls	0	31.0	6.9	60.9	1.2
Peanut butter	3.5	2.3	13.8	74.7	5.8
Sugar	97.7	0	0	1.2	1.2

Dietary intake

Most mothers considered a shortage of food as a major problem contributing to their perceived poor nutritional status of the children in this community. The majority of mothers were more concerned with satisfying their children's basic hunger. They were less interested in the quality of food given. More than 95% of children enjoyed all three main meals (breakfast, lunch and supper). Only preschool children (19%) consumed food between lunch and supper. The type of foods and frequency at which these were usually consumed are given in Table 2. The frequency of consumption of animal foods was generally low. Staple foods mostly consumed were maize meal porridge and rice-and-beans. Almost all children (98%) reported using sugar on a daily basis. Vegetables most often consumed were potatoes, tomatoes, cabbage and *imifino* (a locally grown green leafy vegetable). Fruit was very seldom consumed. Salt was usually added to the food during preparation.

Extra salt was seldom added after dishing up. At the time of the survey iodisation of salt was not yet compulsory hence all households consumed non-iodised salt. Fat was regularly (48% - 98%) added to foods most often consumed. Unfortunately the type of fat was not specified. Almost 70% of primary school children bought food at school.

Serum Micronutrients

The prevalence of micronutrient deficiency both mothers and children is shown in Table 3.

Preschoolers: Seventy-seven percent of children had urinary iodine levels less than 10 µg/dL. Moderate and severe iodine deficiency was prevalent among 32% and 9% of this age group. Anaemia was present among 24%. Iron deficiency, as indicated by serum ferritin and transferrin saturation, was 20% and 44% respectively (Yip *et al.,* 1984). Almost half (45%) were marginally vitamin A deficient (<20 µg/dL). Only 9% of children had low serum vitamin B_{12} levels while 4% had low serum folic acid levels.

Primary school children: Of children aged 6 to 11 years, 22% had either palpable or visible thyroids. Urinary iodine levels below 10 µg/dL were present among 84% of this group of children. Haemoglobin levels below 12 g/dL were observed in 22% of children. Severe iron deficiency was observed in 7% and low transferrin saturation in 32% of primary school children. Half of the children presented with marginal vitamin A deficiency (52%). Serum vitamin B_{12} levels were low in 12% and serum folic acid levels were low in 6% of primary school children.

Mothers: Enlarged thyroids were observed in 27% (n=34) of mothers. Of these 34 mothers 17% were palpable and 9% visible. Anaemia was prevalent in 22%. Serum ferritin levels below 12 ng/mL were observed in 19% of mothers. Transferrin saturation ratios below 16% were present in 28%. Marginal vitamin A deficiency was prevalent among 2% of mothers. The prevalence of vitamin B_{12} (11%) and serum folic acid (8%) deficiency was low.

Table 3. *Prevalence (%) of micronutrient deficiencies of mothers and children*

	Mothers Prevalence (n)	Preschoolers Prevalence (n)	Primary school children Prevalence (n)
Thyroid size			
Grade 2	17 *(22/127)*	3 *(3/105)*	14 *(18/131)*
Grade 3	9 *(12/127)*	2 *(2/105)*	8 *(11/131)*
Urinary iodine (µg/dL)			
< 2	-	9 *(2/22)*	14 *(14/103)*
2 - <5	-	32 *(7/22)*	38 *(39/103)*
5 - <10	-	36 *(8/22)*	32 *(33/103)*
Anaemia[1]	22 *(26/119)*	24 *(25/105)*	22 *(27/123)*
Iron status			
Serum Ferritin[2]	19 *(24/127)*	20 *(19/96)*	7 *(9/126)*
Transferrin saturation[3]	28 *(36/127)*	44 *(40/90)*	32 *(40/124)*
Serum Vitamin A (µg/dL)			
< 10	-	1 *(1/98)*	1 *(1/126)*
10 - < 20	2 *(2/127)*	45 *(44/98)*	51 *(64/126)*
20 - < 30	23 *(29/127)*	49 *(48/98)*	41 *(52/126)*
Serum vitamin B_{12}[4]	11 *(13/122)*	9 *(8/91)*	12 *(14/124)*
Serum folic acid[5]	8 *(10/127)*	4 *(4/91)*	6 *(7/124)*

1 Haemoglobin cut-off values for women and children older than 6 years: <12 g/dL; for children <6 years:<11 g/dL.
2 Serum ferritin for adult women <12 ng/mL and for children <10 ng/mL considered deficient.
3 Transferrin saturation for adult women < 16%; children 6-11 < 15%; children < 6 years < 13%.
4 Vitamin B_{12} cut-off: <150 pg/mL
5 Serum folic acid: <3 ng/mL

Discussion

Although many positive socio-political changes have taken place over the past few years, undernutrition seems to prevail in many communities throughout the country. This rural community in KwaZulu-Natal was no exception. It was clear from the results of this study that malnutrition existed in this rural community. This was indicated by both the direct measurements of micronutrient deficiencies as well as the prevalence of moderate stunting. Although moderate, it is important to discuss the anthropometric data at hand. The doubling in prevalence of stunting from the first to the second year of life in these children was of concern. Stunting is a measure of long term deficiencies indicating previous or ongoing nutritional deficiencies (Brown *et al.,* 1995; Hodge *et al.,* 1991). This increased prevalence persisted throughout the age range studied. Martorell (1990) argues that once present, stunting remains for life and that there is no catch-up growth as many believe. This is partially supported by Schroeder (1995) who found that the impact of supplementation on growth has no effect after 3 years of age. If stunting is not reversed it will lock children in a lower growth trajectory with a lower potential for future growth (Martorell, 1995; Grantham-McGregor *et al.,* 1996). Hence the importance of addressing nutritional deficiencies at a very young age (Castello, 1989). The prevalence of 4.1% for wasting in the 12 - 24 month age group should serve as a warning sign. The WHO recommends a prevalence of more than 4% wasting in children under 5 to be considered high (De Onis *et al.,* 1993).

One could argue that the most probable cause for these deficiencies would be explained by undesirable feeding practices during infancy and early childhood. Although it has been shown that the majority of mothers in this area initiated breast-feeding, additional milk feeds and solid foods were introduced at an early age. In this community the first food given to infants is usually maize meal porridge (Faber *et al.,* 1997). The latter contains inadequate micronutrients if used on its own. The preschool and primary school children consumed a limited variety of foods. The mothers indicated that the type of food was not as important as the satiating effect it has, indicating a serious lack of nutritional knowledge.

The contributing role of diarrhoea to malnutrition should not be underestimated. Water for household use is collected from the Umgeni river which is also used for washing, bathing and swimming. This makes the water from the river a potential health hazard. In addition very few mothers boiled water before use increasing the risk of diarrhoea. From information gathered during the survey it was clear that the treatment of diarrhoea was also not sufficient.

Deficiencies of all three most important micronutrients were found in this community. A high prevalence of moderate iodine deficiency was identified with the highest prevalence among primary school children. This is of great concern as iodine deficiency in school children is often associated with impaired psychomotor development and school performance (Vermiglio *et al.,* 1990; Benadé *et al.,* 1997). At the time of the study compulsory iodisation of salt was not yet introduced. No iodised salt was available from the local shops. In addition, availability and consumption of iodine-rich seafoods was extremely low. More than 50% of the households ate cabbage, a known goitrogen, at least 4 times a week. The high prevalence (26.7%) of an enlarged thyroid among mothers clearly reflected the unavailability of iodised salt. Since the baseline study was carried out compulsory iodisation of salt was introduced. The prevalence of goitre is constantly monitored to see whether it will decline as has been observed in other countries.

Extensive vitamin A and iron deficiencies were prevalent. This was probably due to the poor dietary intakes of vitamin A and iron-rich foods like pumpkin, carrots, spinach and liver, which were seldom eaten. *Imifino,* a locally grown green leafy vegetable of the *Amaranthus spp.,* high in both iron and vitamin A was regularly consumed. However the bio-availability of its iron is not high. In addition, some recent studies have shown that a high consumption of dark green leafy vegetables does not increase the serum concentration of β-carotene (West *et al.,* 1997). The higher prevalence of anaemia and iron deficiency in the younger children was of concern. This could have severe developmental implications during an age when children are most vulnerable.

The high prevalence of overweight in mothers in this community was of concern since hypertension has been found frequently among urban black women where the prevalence of overweight and obesity is high (Steyn *et al.,* 1991). One should emphasise the importance of addressing this problem in the rural areas in an attempt to prevent chronic diseases commonly associated with obesity from taking on epidemic proportions (Steyn *et al.,* 1991).

This is a poor community and mothers have a low educational level, both major determinants of malnutrition (Tonglet *et al.,* 1992). Available resources, land and water are not effectively utilised by the community as they do not possess the necessary skills and financial means to do so. This contributes to inefficient food production and hence limits the variety of consumption. The limited variety of food at the local shops also contributes to the lack of certain important foods in the diet. In this community the prevalence of stunting has not yet reached severe proportions. However, serious micronutrient deficiencies were present. This emphasises the urgency of action to prevent these micronutrient deficiencies to manifest as severe stunting and its associated consequences. The results of this study were used to design and implement an intervention programme to address the nutritional deficiencies existing in this community. The local production of foods rich in vitamin A and iron is currently under investigation by the Agricultural Research Council in close collaboration with the Medical Research Council (MRC) and the community.

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Disadvantaged black and coloured infants in two urban communities in the western Cape, South Africa differ in micronutrient status

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Abstract

Objectives: To determine the nutritional status of urban infants in two disadvantaged communities in the Western Cape, South Africa with special reference to micronutrient status and linear growth.
Design: Cross-sectional study.
Setting: Two disadvantaged urban coloured and black communities in the Western Cape, South Africa.
Subjects: Infants aged 6-12 months.
Results: Stunting and underweight were more prevalent in coloured infants (18%; 7%) compared to black infants (8%; 2%). Anaemia (Hb <11 g/dL) was prevalent in 64% of coloured and 83% of black infants. Iron deficiency anaemia (Hb <11 g/dL and ferritin <10 ng/mL) was found in 32% of coloured infants and in 46% of black infants. Zinc deficiency was prevalent in 35% and 33% in the coloured and black infants, respectively. Marginal vitamin A deficiency (serum retinol <20 μg/dL) was observed in 23% of black infants compared to 2% of the coloured infants. Of black infants 43% and of coloured infants 6% were deficient in two or more micronutrients. Six percent of coloured infants had C-reactive protein concentrations above 5 mg/L compared to 38% of the black infants. The dietary intake of micronutrients was, in general, lower in black infants compared to coloured infants. The overall psychomotor development, assessed by the Denver Developmental Screening Test (DDST), was different between the two groups. The coloured infants scored higher in three out of the four categories as well as in their overall score.
Conclusions: This study shows that only information on stunting and wasting in urban disadvantaged infants is not sufficient to make recommendations about specific community intervention programmes. Information on the micronutrient status, independent of wasting and stunting, is necessary to design nutrition programmes for different communities. The study also showed a substantially higher prevalence of micronutrient deficiencies among urban black infants.

Introduction

The disadvantaged circumstances in which families live in peri-urban communities in developing countries and their consequences on health are reported frequently. Infants growing up in these communities are vulnerable with reference to health and nutrition (Kikafunda *et al.,* 1998; Getaneh *et al.,* 1998).

There are no detailed reports from South Africa comparing the nutritional status of different ethnic groups of infants in disadvantaged communities. Often the age groups studied include a wider age range (Dannhauser *et al.,* 2000; Faber *et al.,* 1999). Conclusions with regard to infants aged 6-12 months are limited in such studies. Specific information on infants is necessary in order to plan community nutrition intervention programmes to reduce the vulnerability of young children at the age of weaning (Jaspers *et al.,* 1999).

Adequate nutritional status is a prerequisite for good physical and mental development of vulnerable communities (Kikafunda *et al.,* 1998; Vazir *et al.,* 1998). In these communities the emphasis is mostly on the nutritional quantity of the food pattern and less on the quality of diet (Faber *et al.,* 1997). Information on the prevalence of stunting and wasting of infants and children in the absence of information on micronutrient status may therefore not be sufficient to judge the nutritional health status (Oelofse *et al.,* 1999).

This study reports on the nutritional health status of 6-12-month-old disadvantaged infants living in two adjacent peri-urban communities historically known as black and 'coloured' communities. We compared the nutritional status of the two groups using both anthropometric and biochemical information.

Methods

Study area and design

The study was done between February and June 1998. The study population came from two adjacent peri-urban communities in the Western Cape, South Africa. The two communities were historically categorised as being 'coloured' (Cloetesville) and black (Kayamandi). It was a cross-sectional study. The aim was to establish the nutritional status of 6-12-month-old disadvantaged infants in these two urban communities in the Western Cape, South Africa. From each of the two communities, 60 children aged 6 - 12 months were randomly selected from all children visiting the local clinic. Appointments were made with the mothers to visit the local day clinics on three occasions during the week to enable the repetition of some of the measurements. Data collection was done over a period of four months. Those who defaulted were visited and accommodated during another session. If a mother-child pair did not default they would complete their three visits within a period of two weeks. In each community two research assistants were trained in all aspects of data collection. The Medical Research Council gave ethical approval for the study.

Anthropometry

Measurements of weight and length were taken without shoes and in light clothing as described by Jelliffe *et al.* (1989). Weight of both infant and mother was measured to the nearest 0.1 kg using a calibrated electronic load cell digital scale (UC-300 Precision Health Scale). Length of infants was measured in the recumbent position on a baby board to the nearest 0.1 cm. Height of mothers was measured using a stadiometer attached to a wall. Anthropometric indicators including z-scores for height-for-age (HAZ), weight-for-age (WAZ) and weight-for-height (WHZ) were calculated using the Epi Info version 6.04a software program (Dean *et al.,* 1993). The prevalence of stunting, underweight and wasting was defined as the percentage of individuals who had a HAZ, WAZ and WHZ score below -2 SD of the National Centre for Health Statistics (NCHS) reference median (Gorstein *et al.,* 1994). The severity of undernutrition was categorised according to the World Health Organization (WHO) (De Onis *et al.,* 1993). Information on low birth weight was obtained from clinic records.

Laboratory analyses

A venous blood sample was collected from each infant. Whole blood was analysed on a Coulter Counter for Hb values. Serum ferritin concentration was determined immuno-radiometrically (Becton Dickinson). Total iron and total iron binding capacity (TIBC) were analysed using Boehring Mannheim kits (cat no. 125806 and no. 1553704, respectively). Transferrin saturation was calculated by expressing total serum iron as a percentage of TIBC. Plasma retinol was determined using a slightly modified version of the reversed-phase HPLC method described by Catignani and Bieri (Catignani *et al.,* 1983). Serum zinc was determined through atomic absorption spectrometry. The determination of C-reactive protein (CRP) was done by particle enhanced nephelometry (N Latex CRP, Behring).

Morbidity

A morbidity questionnaire was completed for each child during the first visit. Information on the occurrence of diarrhoea, upper respiratory tract infections (URTI), skin infections and the presence of any other illness was collected.

Dietary intake

Dietary intake was measured on three non-consecutive days by 24-hour dietary recall. A registered dietician trained the research assistants of both communities in the methodology of the 24h recall during a mutual training session prior to the study. During a pilot study on 20 children the research assistants were observed while fulfilling their activities and final adjustments were made to their methods. Recalls included week days and weekends over a period of two weeks to ensure that the information collected reflected their habitual diet. Data on breast-feeding and weaning practices were also collected by questionnaire. This questionnaire included questions on duration of breast-feeding, weaning practices and introduction of complementary food. Breast milk consumption was estimated at 750 mL/day (Suitor *et al.,* 1993; Wood *et al.,* 1988). Dietary data was encoded using the MRC Food Composition Tables (Langenhoven *et al.,* 1991). Portion sizes were estimated according to the MRC Food Quantities Manual (Langenhoven *et al.,* 1991). The dietary intake was compared to the Recommended Dietary Allowances (RDA) (Subcommittee on the Tenth Edition of the RDAs, 1989).

Denver Developmental Screening Test (DDST)

A questionnaire determining the level of mental and motor development of each child was administered to all children aged 6 - 12 months according to the guidelines set out in the DDST manual (Cools *et al.,* 1976). For this age group items of the age range of 4.9 - 13.5 were selected so as to include easy and more difficult items to accommodate children of all levels of development. There are four categories in the test namely, personal social, language, gross motor and fine motor. The research assistants scored the test based on observations and recalls from both themselves and the mothers. Each child's score was calculated by expressing the number of positive observations as a percentage of the maximum possible positive observation. The DDST scores were calculated as the number of positive scores. Each mother and child was interviewed in a separate room to ensure a peaceful and quiet environment as well as a consistent environment for repeat measures.

Statistical analyses

The SPSS statistical package version 9.0 was used for data analyses. The t-test was used to test for differences between continuous variables with equal variances. For unequal variances the Wilcoxon Sign rank test was used.

Results

Socio-demographic information

Both communities had a low socio-economic status. According to socio-economic criteria used in this study, the black community was more disadvantaged than the coloured community. In the black community the majority of people (80%) live in informal housing whilst in the coloured community the majority (94%) live in brick houses. Only 11% of black households had access to water in their homes as opposed to 81% of coloured households. A similar distribution was apparent with regard to sanitation. Only 11% of black residents had toilet facilities in their dwellings compared to 79% of coloured residents. The majority of coloured households (93%) owned a refrigerator, while 55% of black households owned a refrigerator. In both communities more than 90% had electricity in their homes. However, only 39% of black people used electricity for cooking opposed to 100% in the coloured community. Gas and paraffin were used as alternative means.

Anthropometry

Table 1 shows the general characteristics of the study population. There was very little difference between the two communities with respect to mean weight and height..

Table 1 *General characteristics of coloured and black infants aged 6-12 months.*

	Coloured		Black	
	Mean	SD	Mean	SD
Age (mo)	8.9	1.9	8.3	1.5
Length (cm)	68.6	4.9	68.3	2.7
Lower leg length (mm)	186.0	14.0	185.0	13.0
Weight (kg)	8.6	1.7	8.8	1.2
WAZ[1]	-0.16	1.42	0.31	1.12
HAZ[2]	-0.95	1.30	-0.73	0.84
WHZ[3]	0.76	1.12	1.10[a]	1.01
Underweight (%)	8	-	2	-
Stunting (%)	18	-	7	-
Wasting (%)	0	-	0	-

[1] WAZ=weight-for-age z-score; 2 HAZ=height-for-age z-score; 3 WHZ=weight-for-height z-score. [a] $p<0.05$

The only significant difference was in weight-for-age z-score. The coloured children had a significantly lower mean WAZ score when compared to the black children. Stunting was present in 18% of black and 7% of coloured infants. Underweight was prevalent in 8% of coloured and in 2% of black infants. There was no wasting in either of the two communities. The prevalence of low birth weight (birth weight <2500 g) was 27% in coloured and 10% among black children. Maternal height did not differ between the two communities, however, weight and BMI were higher in the black women

General health

Twenty-eight percent (28%) of black children and 23% of coloured children were reported to have had diarrhoea during the two weeks prior to the clinic visit. URTI were reported in 39% of black and 74% of coloured children during the same period. Skin infections were present in 27% of black and 12% of coloured children.

Micronutrients

Table 2 shows that mean levels of haemoglobin, serum retinol and albumin were significantly lower in black than in coloured infants.

Table 2 *Biochemical indices of coloured and black infants aged 6-12 months.*

	Coloured (n=42) Mean (SD)	Black (n=47) Mean (SD)
Haemoglobin (g/dL)	10.7 (0.7)*	10.4 (0.8)
Haematocrit	31.3 (2.0)	31.1 (2.5)
Serum retinol (µg/dL)	29.1 (5.7)*	24.9 (8.0)
Albumin (g/L)	49.0 (3.2)*	47.2 (4.0)
Total iron (µmol/L)	9.3 (3.8)	7.8 (4.2)
TIBC (µmol/L)	67.4 (9.1)	64.6 (10.2)
Ferritin ng/mL	15.3 (11.2)	19.0 (14.3)
% Saturation	14.2 (6.2)	12.3 (6.4)
Serum zinc (µg/dL)	72.0 (13.3)	74.2 (13.5)

*=p<0.05

Table 3 shows the prevalence of micronutrient deficiencies. Marginal vitamin A deficiency was especially prevalent among blacks (23%). A large number of both coloured (64%) and black (83%) infants were anaemic. The prevalence of low serum iron of black children (50%) was twice that of the coloured children (26%). The prevalence of low serum ferritin was similar in coloured (34%) and black (39%) infants. Both communities had a similar prevalence of zinc deficiency. C-reactive protein, an indicator of infection, was considerably higher in black children (38%) when compared to coloured children (7%). Infants with high CRP levels had significantly ($p<0.05$) higher ferritin levels than those with low CRP levels.

Table 3 *Prevalence (%) of micronutrient deficiencies in coloured and black infants aged 6-12 months.*

	Coloured (n=42)	Black (n=47)
Haemoglobin <11 g/dL[1]	64	83
Total iron <5.4 µmol/L[2]	26 *	50
TIBC >86.0 µmol/L[2]	4	2
Ferritin <10 ng/mL[2]	34	39
% transferrin saturation <8 %[2]	26 *	48
Iron deficiency anaemia[3]	32	46
Vitamin A <20 µg/dL[4]	2 **	23
Vitamin A <10 µg/dL[4]	0	2
Serum zinc <65 µg/dL[5]	35	32
C-reactive protein >5 mg/L[6]	7	38

[1] WHO, 1972; [2]Pilch *et al.,* 1980; [3](Hb<11g/dL and ferritin<10 or saturation <8%)
[4]WHO, 1994; [5]Pilch *et al.,* 1980; [6]Pepys, 1979.
*=p<0.05; **=p<0.01

Zinc deficiency in the presence of iron deficiency was observed in 21% of black and 4% of coloured infants. Eleven percent (11%) of black infants and 2% of coloured infants had vitamin A deficiency together with iron deficiency. Vitamin A deficiency in the presence of zinc deficiency was prevalent among 7% of black infants. Vitamin A deficiency together with zinc and iron deficiency was present among 4% of black infants.

Dietary intake

Most nutrients, apart from vitamin C, were consumed in lesser amounts by black compared to coloured children (Table 4).

Table 4 *Dietary intake of coloured and black infants aged 6-12 months.*

	Coloured (n=48) Mean (SD)	<67% RDA	Black (n=62) Mean (SD)	<67 % RDA	RDA[1]
Energy (MJ)	3.9 (0.9)***	2	3.2 (0.8)	13.4	3.5
Energy from protein (%)	14 (4)	-	10 (3)	-	10-15%
Energy from fat (%)	38 (6)	-	38 (8)	-	30-40%
Energy from carbohydrates (%)	48 (6)	-	53 (6)	-	50-60%
Total protein (g)	32 (13)	4	19 (7)	21	14
Vitamin A (RE)	942 (410)*	0	713 (351)	6	375
Vitamin C (µg)	68 (28)	0	77 (43)	0	35
Vitamin D (µg)	7 (4)*	50	5 (4)	57	10
Vitamin E (µg)	7 (3)**	0	5 (4)	10.4	4
Zinc (µg)	5 (2)***	8	4 (1)	31	5
Folate (µg)	88 (25)***	0	65 (18)	3	35
Iron (µg)	9 (5)*	25	7 (5)	47	10
Calcium (µg)	768 (349)***	0	522 (231)	8	400
Magnesium (µg)	123 (43)***	0	82 (35)	0	40

[1] Subcommittee on the Tenth Edition of the RDAs, 1989.
*p<0.05; **p<0.01; ***p<0.001

Also apparent is the percentage of infants in the black community who consumed less than 67% RDA. Especially the intake of iron, zinc and vitamin D was low.

Psychomotor development

There is a great difference in the psychomotor development as measured by the Denver Developmental Screening test (DDST) scores between the two groups of children (Table 5), hence the difference in total scores. The two groups showed similarities only in the fine motor development scores.

Table 5 *Denver Developmental Screening Test scores of coloured and black infants aged 6-12 months.*

	Coloured (n=39) Mean (SD)	Black (n=59) Mean (SD)
Personal Social	0.97 (0.07)**	0.62 (0.17)
Language	0.78 (0.16)**	0.48 (0.14)
Fine Motor	0.94 (0.13)*	0.90 (0.17)
Gross motor	0.91 (0.20)**	0.76 (0.23)
Total Score	0.90 (0.12)**	0.75 (0.21)

* $p<0.01$; ** $p<0.001$

Discussion

This study indicates that data on stunting and wasting alone is not sufficient indicators for nutritional status of infants in different communities. In order to judge health risks adequately, information on the micronutrient status of such communities is essential.

The weight-for-age Z-scores observed in the coloured infants were significantly lower than in the black infants. This difference is difficult to explain. However, an explanation may be found in the fact that the prevalence of low birth weight is higher in the coloured than in the black infants. The question may be asked if the NCHS reference values are applicable to these communities (Hamill *et al.,* 1979). However, Ulijaszek concluded that, although the NCHS references have their limitations, all major population groupings have a similar growth potential. He argues that observed differences could largely be ascribed to differences in environmental quality experienced. Growth is influenced largely by nutritional status and exposure to and treatment of infectious diseases (Ulijaszek, 1994). A study by Droomers *et al.* supported this by observing Indonesian preschool children of high socio-economic class growing taller and heavier than the NCHS reference population (Droomers *et al.,* 1995). Another observation was the higher BMI in the black women compared to the coloured women. High BMI levels are often observed in black women in South Africa (Oelofse *et al.,* 1996).

The prevalence of common illnesses such as diarrhoea, URTI and skin infections was high in these communities. The high prevalence of micronutrient deficiency could play a crucial role in the aetiology of these infections (Tomkins, 1981; Sepulveda *et al.,* 1988;

Black, 1991; Black, 1998). However, one would expect the prevalence of illness to be higher in the black community due to the higher prevalence of marginal vitamin A deficiency and elevated C-reactive protein concentration (Nestel *et al.,* 1999). The data on infection was predominantly qualitative, hence it may be that the black children had sub-clinical infections not discovered during investigation. The high prevalence of elevated C-reactive protein levels in the black children also explains the slightly higher ferritin levels in these children. Since ferritin is also an acute phase protein it is known to increase with infection. The poor living conditions of the black children may also contribute to the higher prevalence of infections.

The presence of multi-micronutrient deficiencies is an important finding. Many nutrition intervention studies focus on one micronutrient only. In the light of the findings of this study it would be crucial to address micronutrient deficiencies in similar communities with a multi-micronutrient fortification approach. Giving only one micronutrient, e.g. zinc, may potentially be detrimental to a child in creating a higher prevalence of iron deficiency as zinc and iron compete for absorption in the body (Solomons, 1996).

Information on dietary intake provides some explanation for the biochemical deficiency seen in this population. It was clear from the repeat 24-hour dietary recall data that the black children did not consume food sufficient in zinc, iron, vitamin D and total energy. The 47% and 31% of black infants consuming less than 67% of RDA for iron and zinc respectively support this observation. In the coloured community only iron consumption was significantly less than 67% of the RDA (25%). The early introduction of complementary food may also contribute to the deficiencies in micronutrients. In both communities the average age of introduction of complementary food was less than 4 months of age. However, there was a difference in the kind of food introduced in these two communities. The coloured children often received cooked vegetables prepared as part of the adult meals. Although the black children also received traditional food it was most often only maize meal porridge which has a relatively high energy content, but insufficient in essential micronutrients. An important factor to consider is the introduction of commercially manufactured baby foods as a major food source in especially the black children. These products were consumed by more than 80% of the black and approximately 70% of coloured children on a regular basis. One may argue that these foods should supply enough nutrients to address the micronutrient needs of these children. However, the 24-hour dietary recall data showed that the majority of mothers use these products in a diluted form, so much so that it cannot possibly supply the required daily needs. If these products are the major source of food for some of these infants one can understand the existing deficiencies.

The results from the psychomotor developmental tests also showed large differences between the two communities. The performance of the black infants was lower when compared with the coloured infants. The higher prevalence of deficiencies in iron and zinc may have contributed to these differences. Many studies have shown that among undernourished children, mental (Lasky *et al.,* 1981; Martorell *et al.,* 1992; Grantham-McGregor *et al.,* 1996) and motor development (Pollit *et al.,* 1994; Powell *et al.,* 1995) are often below normal. The level of poverty may also contribute to the test results. These children come from homes where often 5 - 6 people live in a two-roomed home. The exposure to toys and other forms of stimulation is very often limited.

Results from this study show that deficiencies in vitamin A, iron and zinc remain a concern among urban disadvantaged coloured and black children. These deficiencies are more prominent among the children of the black community, which comprises the major South African population group. Furthermore, there may be a relationship between these deficiencies and the relatively poorer psychometric test performance in the black infants. With an increasing urban black population the magnitude of the problem may become a serious public health problem.

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4

Adequate appetite in micronutrient-deficient urban black South African infants at the age of 6 months

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Abstract

Objective: To assess the appetite of 6 months old disadvantaged urban black South African infants.

Design: A descriptive study. The *ad libitum* consumption test was used to measure appetite. An acceptable, commonly used infant cereal was used as a test porridge. Porridge preparation was standardised and a standardised test environment was used. Each child completed the appetite test and 24-hour dietary recall on three non-consecutive days within a period of two weeks. The average energy intake from the appetite test was tested against the average daily energy intake as measured by the 24-hour dietary recall as a measure of validity.

Setting: A disadvantaged urban community in the Western Cape, South Africa.

Subjects: A random sample of 50 infants aged 6 months visiting the local health clinic.

Results: The average energy intake from the *ad libitum* consumption test was 312 ±182 kJ. The average daily energy intake as measured by the 24-hour dietary recall was 3326±767 kJ. Both the *ad libitum* consumption test and the 24-hour dietary recall were statistically reproducible. There was no significant association between average daily energy consumption and *ad libitum* energy consumption. No significant difference was observed between breast-fed and non-breast-fed infants in energy intake from the appetite test. Association between the appetite test and serum retinol, iron and zinc concentrations was not significant. Association between knee-heel length and energy intake from the appetite test almost reached significance ($r=0.453; p=0.07$). Neither weight nor total length showed any association with energy intake from the appetite test.

Conclusions: In this study population, the *ad libitum* consumption test proved to be a reproducible test of *ad libitum* food intake in small children. There was no apparent influence of any potential confounding variables on energy consumption during the appetite test. The appetite of infants at the age of 6 months appeared to be adequate.

Introduction

Common consequences of micronutrient deficiencies among infants are linear growth retardation, higher morbidity and reduced psychomotor development, which are crucial components in the general development of the child (Prasad, 1996; Bhandari *et al.,* 1996; Pollit, 1995). Insufficient food availability and inadequate parental feeding practices have been associated with micronutrient deficiency. However, some studies could not find an association between poor nutrition and food availability or poor parental feeding practices. Poor appetite rather than the lack of food or poor feeding practices may partially explain low food intake

(Wright *et al.,* 2000; Bentley *et al.,* 1991). A reduced intake of miconutrients or the presence of fever, diarrhoea, and respiratory illness can cause poor appetite (Brown *et al.,* 1992; Umeta *et al.,* 2000; Brown *et al.,* 1995). Poor appetite in children from the age of 3 – 12 months could be related to low early weight gain and subsequent nutritional deficiencies creating a vicious circle (Piwoz *et al.,* 1994). The restoration of appetite may therefore play an important role in the prevention or treatment of nutritional and health problems of young children in developing countries (Engle *et al.,* 1996).

The latest recommendations of the World Health Organization (WHO) on exclusive breast-feeding until the age of 6 months will have implications for the development and introduction of complementary food to this specific age group (WHO, 2000). A reduced appetite at the age of introduction of complementary food may negatively influence growth and development of the child.

An accepted definition of appetite is that it is a process that directs eating and guides moment-to-moment selection of food. It consists of different specific appetites for specific foods and determines which particular food will be chosen, the rate of ingestion and the amount that will be consumed (Blundell *et al.,* 1979). For the appetite test in this study the *ad libitum* consumption test was used (Dossa *et al.,* 2001; Cohen *et al.,* 1995). By using this test appetite is measured by offering a food *ad libitum* to the child followed by assessing the quantity of food consumed. The test food needs to be neutral, culturally acceptable, easily available and commonly palatable so that it would be accepted by the majority of the children and eaten to appease appetite rather than for its novelty or liking (Hadju *et al.,* 1996).

In this study the adequacy of the appetite of infants at the age of 6 months from a disadvantaged urban South African population will be studied.

Subjects and Methods

Study area

Participants in the study were from a black disadvantaged community, Kayamandi, in the Western Cape, South Africa. It has a population of approximately 12000 people. The community has a low socio-economic status with poor health and sanitation conditions. The majority of people live in small informal houses. Almost half of the residents do not earn a regular income. One clinic serves the health needs of the community.

Subjects

Participants in the study were randomly selected from all mothers visiting the local clinic with their infants. A sample of 50 infants was selected. Complete records of 39 of these infants were available for analyses. Informed consent was obtained during home visits when appointments were made with mothers or caretakers to visit the local clinic with their infants. The Ethics Committee of the Medical Research Council approved the study.

Methods and Design

Appointments were made with participants to visit the clinic on three non-consecutive days within a maximum period of two weeks. During these three visits anthropometric measurements, blood collection, 24-hour dietary recall and the appetite test were conducted. The appetite test and 24-hour dietary recall were conducted on each of the three days. Mothers were instructed not to feed the infants prior to the appetite test, which was conducted early in the morning.

To establish which porridge to use as a test porridge during the appetite test a questionnaire was administered to the mothers of 60 infants containing questions on the type and use of porridge usually consumed by their infants. From this questionnaire it was clear that the majority of infants consumed commercially manufactured infant cereals on a regular basis. During a subsequent test on 15 mothers a commonly used infant cereal was consumed and tested for acceptance.

The preparation of the test meal was standardised. For each child 30 g of dry porridge was weighed off on an electronic load cell scale (CASBEE micro weighing scale MW 1200) to the nearest 0.1 g. Water was boiled and left to cool to 50°C after which 90 mL was added to the dry porridge and mixed to obtain an acceptable consistency. The weight of the wet porridge was noted. The mean energy intake from the porridge consumption and daily energy was calculated using the South African MRC food composition database and Food Quantities Manual (Langenhoven *et al.,* 1991; Langenhoven *et al.,* 1991) and expressed in kJ. Each bowl of porridge contained approximately 489 kJ. Energy intake from the test porridge was calculated as a percentage of the total energy (489 kJ) per bowl. The porridge was served to the children at approximately 40°C. The eating environment and utensils for each child were standard. Mothers were also requested to cause the least distraction during the test and act as normal as possible.

Anthropometric measurements

The weight and recumbent length of each child was recorded. Each child was weighed without clothes to the nearest 0.1 kg using an electronic load cell scale (Masskot scale model UC 300). Recumbent length was measured to the nearest 0.1 cm using a baby board. Weight-for-age (WAZ), height-for-age (HAZ) and weight-for-height (WHZ) were calculated using the Epi Info version 6.04 computer program (Dean *et al.,* 1993; Hamill *et al.,* 1972). The knee-heel length of each child was measured using a knemometer (type KNB, Force Institute, DK-2605 Bronby Denmark) (Michaelsen, 1997). Each measurement consisted of 3 sets of 5 readings.

Blood analyses

A 5 mL venous blood sample was collected from each infant. Total iron was analysed using Boehring Mannheim kits (cat no. 125806). Serum retinol was determined using a slightly modified version of the reversed-phase HPLC method described by Catignani and Bieri (Catignani *et al.,* 1983). Serum zinc was determined through atomic absorption spectrometry.

Dietary recall

On the morning of the appetite test a 24-hour dietary recall was conducted on each child. This dietary recall included information on dietary intake from the 24 hours preceding the appetite test. Hence, it included intake during the night and before the test, if any. Trained research assistants conducted the 24-hour dietary recall according to standard procedures (Cameron *et al.,* 1988). Dietary data was encoded and computerised using the MRC food composition database and Food Quantities Manual (Langenhoven *et al.*, 1991; Langenhoven *et al.,* 1991). The nutrient content and energy values were calculated using the MRC food composition database (Langenhoven *et al.,* 1991). Breast milk intake was estimated at 750 mL/day (Suitor *et al.,* 1993; Wood *et al.,* 1988).

Statistical analyses

Both daily energy intake and energy intake from the test meal were normally distributed. Reproducibility was tested using the within-subject day-to-day variation as an indicator for reproducibility. The mean square of the residual from analyses of variance was used as an estimate of the within-subject day-to-day variation. With the appetite test procedures standardised, this meant that the main effects were being limited to subject and day. In this case there was no day effect so the main effect, subject, was taken into account in the Analyses of Variance (ANOVA) and the residual variance was used as the within-subject-day-to-day variance. The Pearson correlation coefficient was used to measure association between daily energy intake and energy from the *ad libitum* consumption test. The Pearson correlation coefficient was also used to test for significant associations between energy intake during the *ad libitum* consumption test and serum concentrations of iron, zinc and retinol, as well as anthropometric indices. A 5% significance level was chosen. Due to the large day-to-day variation in energy intake during the test, the calculated correlation coefficient was weakened. A correction was made using the attenuated correlation coefficient.

The Statistical Package for Social Sciences (SPSS 10.04 for Windows; SPSS Inc., Chicago) was used to analyse the data.

Results

Table 1 shows the general characteristics of infants at the age of 6 months

Table 1 *General characteristics of 6-month-old infants.*

	Mean (SD) n=44
Age (mo)	6.2 (0.4)
Birth weight (kg)	3.12 (0.42)
Weight (kg)	8.0 (1.1)
Height (cm)	65.0 (2.9)
WAZ	0.59 (1.15)
HAZ	- 0.63 (1.14)
WHZ	1.36 (1.08)
Lower-leg-length (mm)	175.99 (8.9)
Serum retinol µg/dL	29.5 (6.8)
Iron µmol/L	10.1 (4.1)
Zinc µg/dL	72.1 (14.2)

The anthropometric indices of these 6-month-old infants showed no obvious signs of undernutrition.

Table 2 *Average daily and* ad libitum *energy intake of 6-month-old infants over 3 days*

	Day 1	Day 2	Day 3	Average over 3 days
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
Daily energy intake (kJ) from 24-hour dietary recall	3263 ± 853 (n=37)	3257 ± 882 (n=37)	3182 ± 906 (n=34)	3326 ± 767 (n=34)
Ad libitum energy intake (kJ) during test meal	284 ± 162 (n=44)	323 ± 206 (n=41)	323 ± 252 (n=39)	312 ± 182 (n=39)

The average energy intake during the appetite test and the average daily energy intake as measured by the 24-hour dietary recall is shown in Table 2.

The average daily energy intake (3326±767 kJ) was within the recommended daily allowance for daily energy intake for infants aged 6 months (3570 kJ) (Subcommittee on the Tenth Edition of the RDAs, 1989).

The results from the appetite test showed significant between-subject effects ($p<0.001$), but no within-subject day effect was present. Five infants were excluded in computing the mean values for the third and combined days because they did not complete all three appetite tests successfully. The energy intake from the appetite test contributed an average of 10.0 % to the average daily energy intake.

There was no difference in percentage energy contributed by the appetite test to total average daily energy intake between infants being breast-fed (10.1%) at the time of the study compared to infants not breast-fed (9.8%). Breast-fed infants had a significantly higher average daily energy intake compared to non-breast-fed infants (Table 3). However, there was no significant difference in energy intake from the test meal, even though the average energy intake of the breast-fed infants from the test meal appeared considerably higher than that of the non-breast-fed infants.

Table 3. *Comparison of daily energy intake and energy intake from* ad libitum *consumption test meal between 6-month-old breast-fed and non breast-fed infants.*

	Breast-fed (n=16) Mean ± SD	Non-breast-fed (n=21) Mean ± SD
Average daily energy intake (kJ)	3584.3[a] ± 459.9	2784.1 ± 848.7
Average energy intake from test meal (kJ)	341.6 ± 186.2	259.9 ± 174.6

[a] difference significant between breast-fed and non-breast-fed infants at $p< 0.05$

No significant association was found between the average daily energy intake and the energy intake from the test meal ($r=-0.175$; $p=0.301$). This was true for both breast-fed and non breast-fed infants. Serum retinol, iron and zinc concentration did not show any significant correlation with energy intake from either daily energy intake or energy intake from the test meal. No association was observed between energy from the test meal and weight and height. The association of knee-heel length with energy intake from the test meal almost reached significance (r=0.45; p=0.07).

The incidence of diarrhoea was very low with only 10% of mothers responding that their infants had diarrhoea during the past month. Incidence of skin infections was only 2%. The incidence of upper respiratory tract infections (URTI) was considerably higher (28%). There was no significant difference in the energy intake from the appetite test between infants with URTI and those without.

Discussion

Reduced appetite can be the consequence of illness, helminthic infection or deficiencies in one or more crucial micronutrients. One of the obvious consequences of a reduced appetite is a reduced food intake. In addition, food availability, accessibility and food choices can influence reduced food intake. In this study population, food availability and accessibility were not of primary concern as the community formed part of a large town where food was readily available and accessible. In this study, the option of helminthic infections was ruled out as analyses of stool samples revealed no helminthic infestation. The association between a lack of appetite and micronutrient status has often been illustrated in studies where anti-helminthic treatment has resulted in an increased appetite. This could most probably be ascribed to the restoration of nutrient uptake among which will be essential micronutrients (Hadju *et al.,* 1996; Latham *et al.,* 1990). It seems that food choices play the most important role in food intake of infants in this community. Hence, incorrect food choices resulting in a low intake of micronutrients may partially explain possible reduced appetite.

The importance of a reduced appetite lies in the indirect negative effect on linear growth. Thus the restoration of appetite may play an important role in the prevention or treatment of nutritional deficiencies in young children (Den Buitelaar, 1998). The availability of a simple, reliable tool to measure appetite and predict infant food intake, difficulties that need follow-up, would contribute greatly in assessing food intake in young children.

In this study, the lack of a significant association between the daily energy intake, used to validate the appetite test, and the energy intake from the test meal could have many causes. Firstly, the 24-hour dietary recall may not be the most appropriate method to compare with the *ad libitum* consumption test. The 24-hour dietary recall often overestimates food consumption. The average daily energy consumption was indeed high for infants of this age (Ralph, 2000). However, it is often found in these settings that high amounts of energy-rich foods insufficient in micronutrients are consumed (Oelofse *et al.,* 1999). In a study in Benin in 18-30-month-old infants, a significant association was found between energy intake from the *ad libitum* consumption test and the daily energy intake as measured with the weighed food record (Dossa *et al.,* 2001). The weighed food record may be a more accurate measure of daily food intake. Secondly, the 24-hour dietary recall measures daily energy intake, whilst the *ad libitum* consumption test measures energy intake of only one meal after an overnight fast. The variability of the two measurements could thus differ which may affect measures of association.

The difference in energy intake from the test meal between infants could possibly be ascribed to individual differences in the control of food intake (Birch *et al.,* 1995). Although individual variation also exists among these infants the overall within-subject variation was not statistically significant (DeHeeger *et al.,* 1996). This could be due to the limited variety of food and the lack of independent feeding at this age.

The presence of illness has a definite negative impact on appetite. URTI (27%) was the only morbidity observed in significant numbers of infants. However, there was no association between URTI and the average daily energy intake or the energy intake from the test meal. Other more severe diseases such as human immuno-deficiency virus (HIV) infection and tuberculosis (TB) possibly obscure these results. The prevalence of infections like HIV and TB are not known in these communities, but it is estimated that 10% of all children may be infected with HIV. Some studies have shown that HIV can modulate appetite and nutrient absorption (Mannick *et al.,* 1996). It is also known that TB occurs frequently in these communities and often remains undetected in young children. This may negatively affect appetite among these 6-month-old infants (Maltezou *et al.,* 2000). None of the infants in the study sample was tested for HIV or TB due to ethical and practical reasons. None of the mothers or nursing personnel spontaneously confirmed the presence of either of these infections in any of the children. Thus, influences of these infections on appetite and on the association between illness and appetite could not be investigated.

Approximately 50% of infants were breast-fed at the time of the study. Breast milk intake does not change during incidence of illness since infants will continue breast-feeding whilst refusing other foods. Breast-fed children are less likely to reduce their total daily energy and nutrient intakes during spells of illness whereas they may show a reduced intake of the test meal (Huffman *et al.,* 1991). Breast-fed infants self-regulate their total energy intake when other foods are introduced (Cohen *et al.,* 1995). One may expect a difference in energy intake from a test meal between breast-fed and non-breast-fed infants due the fact that breast-fed infants have a significantly higher average daily energy intake when compared to non-breast-fed infants. This may result in either an increase or decrease in energy intake from the test meal. However, in our study similar energy intake from the appetite test was observed in both breast-fed and non-breast-fed infants. Results from studies show that delaying the introduction of complementary food until 6 months does not adversely affect appetite and food acceptance in breast-fed infants (Cohen *et al.,* 1995). Thus, the intake of the test porridge should not be influenced by breast feeding practices.

The association between poor appetite and failure to thrive has been demonstrated by some studies (Cohen *et al.,* 1995; Brown *et al.,* 1992). However, no association was observed between appetite and linear growth. Supplementation with zinc could markedly improve appetite and reduce the incidence of anorexia as well as increase the growth rate of stunted children to that of non-stunted infants. This would appear to be due to, at least in part, a reduction in morbidity from infection and increased appetite (Umeta *et al.,* 2000). However, in this study the serum zinc concentration showed no association with the *ad libitum* consumption test. Body size is an important determinant of energy expenditure. Therefore one could expect infant body mass to influence energy intake and thus appetite (Thomessen *et al.,* 1992; Drewett *et al.,* 1999). However, there was no association between body weight and energy intake from the *ad libitum* consumption test.

This study demonstrates that the measurement of *ad libitum* food intake is reproducible in disadvantaged urban infants at the age of 6 months. The results also indicate that the appetite of these infants have not yet been affected by possible nutritional deficiencies and appeared to be adequate. It is suggested that studies on the validity of the appetite test be continued. The use of a more precise measure of overall food intake in this age group e.g. the 24-hour weighed food record is suggested.

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5

The effect of a micronutrient-fortified complementary food on micronutrient status, growth and development of 6-12-month-old disadvantaged urban South African infants

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Abstract

Objectives: To study the effectiveness of a multimicronutrient-fortified complementary food on the micronutrient status, linear growth and psychomotor development of 6-12-month-old urban disadvantaged South African infants.
Design: Intervention study.
Setting: A black urban disadvantaged community in the Western Cape, South Africa.
Subjects: Infants aged 6 months followed up to the age of 12 months.
Results: In both experimental and control groups serum retinol concentration showed a decline over the intervention period of 6 months. The decline was less pronounced in the experimental group. This resulted in a significantly ($p<0.05$) higher serum retinol concentration at 12 months in the experimental group (26.8±5.8 µg/dL) compared to the control group (21.4±5.7 µg/dL). Serum iron concentration also declined over the intervention period. The decline was less pronounced in the experimental group. No difference was observed in haemoglobin levels between the groups at 12 months. Serum zinc concentration did not differ significantly between the two groups at follow up. Weight gain over the 6 months period did not differ significantly between the experimental (2.1±0.9 kg) and control groups (2.1±1.2 kg). There was no difference in linear growth between the experimental (10.0±1.5 cm) and control group (10.1±2.1 cm) at the end of the follow up period. Weight and length at 6 months significantly predicted weight and length at 12 months. No difference was observed in psychomotor developmental scores between the two groups after six months of intervention.
Conclusions: Introducing a multimicronutrient-fortified complementary food into the diet of 6–12-month-old infants seemed to have an arresting effect on declining serum retinol and iron concentration in the experimental group. No benefit was observed in serum zinc concentration, linear growth and psychomotor development.

Introduction

Research has shown that the development of stunting occurs in a relatively narrow age window. Because of the fact that stunting is most often a sign of chronic nutritional deficiencies, the problem usually has its origin at an earlier age, mostly from the age of 2-4 months. This is generally associated with the age of introduction of complementary feeding (Brown *et al.,* 1995). Once present, stunting could remain for life and there may be no catch-up growth as many believe. If stunting is not reversed or addressed at an early stage it could lock children in a lower growth trajectory with a lower potential for future growth. This will inevitably go together with the associated detrimental consequences of stunting including impaired psychomotor development (Martorell *et al.*, 1990; Schroeder *et al.*, 1995). This emphasises the importance of addressing the problem at an age when nutritional deficiencies are most likely to start.

Children suffering from stunting as a consequence of micronutrient deficiencies often present with below normal psychomotor development (Grantham-McGregor *et al.*, 1996). A more serious consequence is the long term deficits in mental performance (Grantham-McGregor, 1991; Grantham-McGregor *et al.*, 2000; Walker *et al.*, 2000). These children are also usually at a higher risk of morbidity and often have impaired immune function (Pelletier, 1994; Chandra *et al.*, 1991).

It is often not the availability or accessibility of food, but poor infant feeding practices that contribute mostly to deficiencies seen in these children (Gulden *et al.*, 2000). Introducing single or multi-micronutrients to the diet of young children has been proven to be successful in addressing linear growth retardation and morbidity (Sazawal *et al.*, 1998; Umeta *et al.*, 2000; Williams *et al.*, 1999). In this study we introduced a multimicronutrient-fortified complementary food into the diet of 6 to 12-month-old disadvantaged South African infants and studied the effect on micronutrient status, linear growth and psychomotor development.

Subjects and Methods

Study area

The study sample came from an urban disadvantaged black community, Kayamandi, in the Western Cape, South Africa with approximately 12000 inhabitants. This community has a low socio-economic status as indicated by type of housing, possession of household appliances and access to basic amenities. More than 30% of the population had either low or no formal education. Most of the inhabitants worked in the industries in the city or as domestic workers in private homes. Hence, many infants were in the care of grandparents or other family members.

Subjects and design

From this community 60 children aged approximately 6 months were randomly selected from all mothers visiting the local clinic with their infants. The study was designed as an intervention study to establish the effectiveness of a micronutrient-fortified complementary food in the diet of 6-12-month-old black South African infants on their micronutrient status, linear growth and psychomotor development. The study was done between March 1999 and June 2000. Selection criteria included infants with birth weight ≥2.5 kg and no congenital abnormalities. Appointments were made with the mothers to visit the local day-clinic in the community. Each mother visited the clinic on three occasions when the infants were approximately 6 months old and again when the infants were approximately 12 months old. These three visits at 6 and again at 12 months had to be completed within a period of two weeks for each infant. The purpose of the three visits at both 6 and 12 months was for the repeat measurements of the psychomotor test, as well as collection of questionnaire, anthropometric and biochemical data. A minimum of one week was needed between repeat measures of the psychomotor test to minimise a learning effect (Cools *et al.,* 1976). Participants who defaulted were followed-up and accommodated during another session. If a mother-child pair did not default they would complete their three baseline visits within a period of two weeks. The same would hold true at 12 months. In between baseline and follow up research assistants visited participants weekly at home. Some infants were lost to the study due to leaving the study area. Three research assistants were trained in the aspects of methodology used and data collection. The research assistants interviewed each mother or caretaker accompanying the infant in an enclosed room to ensure no distraction during data collection.

Intervention

Each infant was randomly allocated to either an experimental or a control group. The experimental group received a micronutrient-fortified complementary food throughout the six month period while the control group did not receive any complementary food, but continued their normal diet. Prior to the intervention, information on consumption of complementary food was collected by means of a questionnaire. From this information it was clear that the majority of infants (90%) received commercially prepared complementary foods on a regular basis. For this reason the complementary food given to the experimental group was similar to what was well-known and used in the community. However, the quantity prescribed for use per day during the intervention was 60 g of dry cereal and would ensure consumption of 100% of RDA for vitamin A, 80% for iron, and more than 100% for zinc. The composition of the test porridge is given in Table 1. Zinc was in the form of zinc sulphate and iron as ferric pyrophosphate.

After the third visit during the baseline study the mothers with infants in the experimental group received sufficient infant cereal to last approximately 1½ weeks. They received demonstrations on how to prepare the porridge and a measuring spoon to ensure the correct amount of porridge to be consumed. Each child was expected to consume 60 g of dry porridge mixed with cooled boiled water per day for six months.

Table 1. *Composition of fortified infant cereal consumed by experimental group.*

Nutrient	Unit	Per 60 g dry product	%RDA[1]
Energy	kJ	1304	42
Protein	g	12	86
Fat	g	6	-
Carbohydrate	g	54.8	-
Vitamin A	**IU**	**1200 (420)**[2]	96
Vitamin C	mg	40	114
Vitamin B_1	mg	0.64	160
Vitamin B_2	mg	0.24	128
Niacin	mg	3.2	53
Calcium	mg	368	61
Iron	**mg**	**8 (8.8)**[2]	80
Vitamin D	IU	160	40
Vitamin E	IU	4	72
Biotin	µg	20	40
Folic acid	µg	17.6	50
Pantothenic acid	mg	0.6	40
Vitamin B_{12}	µg	0.6	120
Vitamin B_6	mg	0.24	40
Phosphorous	mg	232	46
Iodine	µg	26	52
Zinc	**mg**	**5.6 (0)**[2]	112
Potassium	mg	632	50
Sodium	mg	272	36
Chloride	mg	440	36

1. Subcommittee on the Tenth Edition of the RDAs, 1989.
2. Values in brackets are of the comparable cereal consumed by the control group.

At intervals of one week the research assistants paid home visits to deliver the next batch of infant cereal to the experimental group. These visits were also used to check cereal consumption by the infant. Before commencement of the study mothers gave informed consent. The Ethics Committee of the Medical Research Council approved the study.

Methods

Blood analyses

A 5 ml venous blood sample was collected from each infant from the ante-cubital vein for the analyses of serum retinol, iron and zinc concentration. Serum retinol was determined using a slightly modified version of the reversed-phase HPLC method described by Catignani and Bieri, 1983. Whole blood was analysed on a Coulter Counter for haemoglobin (Hb) values. Total iron was analysed using a Boehring Mannheim kit (cat no. 125806). Serum zinc concentration was determined by atomic absorption. Blood samples could not be obtained from all infants. Reasons for failure to obtain blood samples included refusal by the mother, unsuccessful blood collection and collection of too small amounts of blood for analyses.

Weight and Length measurements

The weight of infants was measured without clothing to the nearest 0.1 kg using a calibrated electronic load cell digital scale (UC-300 Precision Health Scale). The length of infants was measured three times in the recumbent position on a baby board to the nearest 0.1 cm. The average of the three readings was used. Height-for-age (HAZ), weight-for-age (WAZ) and weight-for-height (WHZ) Z-scores were calculated using the Epi Info computer program version 6.04 (Dean *et al.,* 1993).

Baseline infant food intake

Daily dietary intake was measured on three non-consecutive days by 24-hour dietary recall at 6 months of age (Cameron *et al.,* 1988). To obtain information on breast feeding and weaning practices data on breast feeding and use of complementary food was collected by questionnaire.

Psychomotor test

The Denver Developmental Screening Test (DDST) was used to establish psychomotor development. A questionnaire determining the level of mental and motor development of each child was completed for all children at 6 months and again at 12 months according to the guidelines set out in the DDST manual (Cools *et al.,* 1976). The test was done twice at both 6 and 12 months. For every age group specific items were selected. This would include easy and more difficult items to accommodate children of all levels of development. There were four categories in the test namely social adaptive, language, gross motor and fine motor. The DDST score of each child was calculated by expressing the number of positive observations as a percentage of the maximum possible positive observations. Research assistants conducted the psychomotor test. The test took place in an enclosed room to ensure no distraction. It also ensured a consistent environment for repeat measurements. Research assistants had been thoroughly trained to ensure correct and consistent execution of the test items. A senior research worker supervised the execution of the test.

Statistical analyses

Anthropometric indices for HAZ, WAZ and WHZ were calculated using the Epi Info version 6.04 computer program (Dean *et al.,* 1993). This program uses the NCHS reference population data (Hamill *et al.,* 1979) for calculating anthropometric indices. In normally distributed data comparison of means between groups was done with the unpaired t-test. In data not normally distributed the Wilcoxon sign rank test was used. For measures of association between numerical variables the Spearman's rho correlation coefficient was used. For categorical data the Chi square test or Fisher's exact test for cell sizes less than five was used. Data was analysed using SPSS version 10.04 for windows (SPSS 10.04 for Windows; SPSS Inc, Chicago). The significance level was taken at $\alpha = 0.05$.

Results

Micronutrient status

Table 2 shows the serum retinol, iron and zinc concentration at 6 and 12 months for both the experimental and control groups. In both groups serum retinol concentration declined over the six month intervention period. The decline was greater in the control group. This resulted in serum retinol concentration at 12 months being significantly ($p<0.05$) higher in the experimental group (26.8±5.8 µg/dL) when compared to the control group (21.4±5.7 µg/dL). Haemoglobin concentration remained similar from baseline to follow-up in both groups. During the six months follow up the total serum iron levels declined in both groups. The decline was more pronounced in the control group, however, no significant difference was observed. Serum zinc levels differed greatly at baseline and at follow up between both experimental and control groups. There was no significant difference in increase in serum zinc concentration between groups over the intervention period.

At baseline serum retinol concentration showed a positive significant association (0.56; $p<0.01$) with serum iron concentration which disappeared after 6 months. At 12 months serum retinol concentration showed a significant association ($r=0.54$; $p<0.01$) with haemoglobin concentration.

Table 2. *Micronutrient status of experimental and control group at the age of 6 months and at 12 months.*

	At 6 months		At 12 months	
	Experimental n=25 Mean (SD)	Control N=21 Mean (SD)	Experimental n=16 Mean (SD)	Control n=14 Mean (SD)
Serum retinol (μg/dL)	30.5 (7.4)	28.8 (6.6)	26.8 (5.8)	21.4 (5.7)[a]
Total iron (μmol/L)	10.6 (4.4)	9.6 (4.0)	8.0 (3.2)	6.5 (3.9)
Hb (g/dL)	10.8 (1.0)	10.3 (1.0)	10.8 (0.9)	10.6 (1.3)
Zinc (μg/dL)	79.3 (12.1)	69.1 (15.8)	85.0 (9.1)	73.6 (12.1)

[a] significant difference at 0.05 level.

Anthropometry

The age, weight and total length were similar for both experimental and control groups at 6 months (Table 3). After the intervention period at 12 months no significant difference was observed in weight or length between the experimental and control groups. Weight gain did not differ between the experimental (2.1±0.9 kg) and the control group (2.1±1.2 kg) after 6 months of intervention. No difference was observed in linear growth between the experimental (10.0±1.5 cm) and the control group (10.1±2.1 cm) after intervention.

The mean Z-scores for HAZ, WAZ and WHZ were similar between the two groups at both 6 and 12 months. The mean Z-scores for all three indices decreased over the six months intervention period. No difference was observed in magnitude of difference in Z-scores after the intervention in any of the three indices between the experimental and control groups.

At baseline the psychomotor test results did not differ between the experimental (67.8 ± 8.3) and the control group (64.3 ± 10.3). Neither was any significant difference in test scores observed between the experimental (83.0 ± 10.9) and the control group (88.2 ± 9.0) at 12 months.

Table 3 *Anthropometric variables of the experimental and control groups at the age of 6 months and at 12 months.*

	At 6 months		At 12 months	
	Experimental	Control	Experimental	Control
	N=25	n=21	n=16	n=14
Age (mo)	6.2 (0.4)	6.1 (0.4)	13.7 (0.6)	13.4 (0.6)
Weight (kg)	7.6 (0.6)	7.8 (1.2)	9.6 (1.0)	9.9 (1.8)
Length (cm)	64.4 (1.5)	64.6 (3.1)	74.4 (1.8)	74.5 (3.1)
WAZ	0.71 (1.10)	0.46 (1.21)	-0.55 (0.99)	-0.52 (1.60)
HAZ	-0.68 (1.35)	-0.57 (0.87)	-0.94 (0.70)	-0.72 (1.10)
WHZ	1.58 (1.10)	1.11 (1.10)	0.11 (1.10)	0.42 (1.60)

The composition of the test differed for baseline and follow-up due to age difference, thus no comparison was made for the difference between baseline and follow-up, but only between groups at both 6 and 12 months.

Discussion

In this study, consumption of a fortified complementary food appeared to have a positive effect on serum retinol and to a lesser extent iron concentration. No effect was observed on serum zinc concentration, linear growth and psychomotor development. Mean serum retinol concentration was significantly higher in the experimental group, however, the difference between groups in change in retinol concentration from baseline to follow up did not reach significance. The significantly higher serum retinol concentration in the experimental group may have been due to the higher intake of dietary vitamin A preventing a similar decline in serum retinol levels as seen in the control group over the six-month period. The level of fortification with vitamin A was 96% of RDA. Other intervention studies using fortified complementary food also found a positive association of dietary vitamin A with serum retinol in the experimental group (Lartey *et al.,* 1999). In the latter study the control groups had a decline in vitamin A status similar to what was observed in the control group of the current study. In the mentioned study a slight increase in serum retinol in the experimental group was observed. In this study a decline in serum retinol was observed in both groups. The consequences of the potential prevention of decline in serum retinol would positively impact on morbidity (Lartey *et al.,* 2000; Dudley, 1997; Fawzi *et al.,* 1999) and the efficacy of immunisation (Bhaskaram *et al.,* 1997), especially in this age group.

The lack of significant differences in serum iron concentration between the two groups at the end of intervention could possibly be ascribed to the type of iron fortification. Iron in the fortified cereal was in the form of ferric pyrophosphate, a form of iron less bio-available than for example iron in the form of ferrous fumarate (Davidsson *et al.,* 2000).

At baseline the mean serum zinc concentration was visibly higher in the experimental group. This could possibly explain the higher levels of serum zinc in the experimental group at follow-up. Although some studies showed a significant positive association between serum zinc and anthropometric measurements, it was not observed in our study (Umeta *et al.,* 2000). However, a lack of association was found in other zinc supplementation studies (Friis *et al.,* 1997; Kikafunda *et al.,* 1998). The low prevalence of stunting may have contributed to this lack of association. Stunted children respond better than non-stunted children to zinc supplementation with regard to linear growth (Umeta *et al.,* 2000).

In our study we found no significant difference in linear growth between infants receiving a fortified weaning food and infants in the control group. The prevalence of stunting in our population was low compared to neighbouring African countries where the prevalence can vary from 36% in Mozambique to 44% in Lesotho (WHO, 2000; Hautvast *et al.,* 2000; Haidar *et al.,* 1999). The absence of significant changes in any of the anthropometric parameters may be explained by the short follow up period of six months. However, the mean difference in weight and height from baseline to follow up (2.1±0.9 kg; 10.0±1.8 cm) seemed great enough to have shown a difference if there was a true difference. With the current sample size a difference between groups of an increase of more than 2 cm in height between baseline and follow-up would have been detected in this study at a power of 80%. In a zinc supplementation study of similar duration in the same age group by Umeta *et al.,* (2000), they observed a difference in increase in height over the intervention period between stunted groups of more than 4 cm and between non-stunted groups of 1.6 cm.

Breast-feeding and complementary feeding practices could also have contributed towards explaining the lack of a pronounced effect of fortification on the outcome measures. The average age of cessation of breast-feeding was 3 months. At this age the introduction of complementary food was common. This may have influenced the actual intake of the fortified cereal. Infants may have been used to a greater variety, eventually resulting in reports of infants refusing the cereal due to being tired of it. However, data collected on type of weaning food consumed revealed that a large proportion of the diet of these infants consisted of commercially fortified infant cereal eaten on a regular basis, therefore the decision to have the control group maintain their habitual diet (Morley *et al.,* 1999).

The lack of a significant difference in psychomotor development scores at follow up is difficult to explain. Many studies have shown a significant association of iron deficiency anaemia with impaired psychomotor development (Morley *et al.,* 1999; Williams *et al.,* 1999; Pollit, 1995). It has also been shown that infants consuming an iron-fortified milk had a less pronounced decline in psychomotor development (Williams *et al.,* 1999). One would expect higher DDST scores for the experimental group. However, some iron fortification studies have found no difference in psychomotor developmental performance between infants receiving an iron-fortified food and infants in a control group (Morley *et al.,* 1999). The relatively low prevalence of undernutrition may also explain the lack of difference between the experimental and control groups (Benefice *et al.,* 1999). The relatively high scores observed in both groups after six months suggest that at least for this age group psychomotor development seems not to have been impaired to a great deal.

The high percentage of default may be explained by a few possible factors. Perceptions of better health care in the city attract thousands of prospective mothers. They come to the city and stay with relatives or friends during the antenatal period. Often incorrect addresses are given in fear of being persecuted. During this time the local health clinics are frequented for antenatal care. After delivery these mothers continue their clinic visits with the newborn for a varying period of time, but many return to their home area after the infant has reached the age of 6 months and has completed the immunisation schedule. This complicates the recruitment and follow up of infants. In addition to this primary cause of default, another important contributory factor is the annual migration. Over the Christmas and New Year period many people visit their home areas and some return only after a few months. To only include those remaining would contribute to bias. In planning the study we considered these aspects and planned accordingly, but never envisaged the extent of these issues. The recruiting also posed difficulties not anticipated. Finding participants based on given addresses often ended in hours of searching due to incorrect and non-existing addresses. Intervention studies in urban populations, especially among the very young will always remain problematic with respect to defaulting. In order to address these difficulties one would need to increase the time allocated to recruitment and follow up as well as the initial sample size to compensate for any loss of participants due to the reasons given earlier.

In conclusion, the significantly higher serum retinol levels observed in the fortified group may hold promise for further studies on food fortification. The associated higher levels of serum iron may reach significance in larger studies. In the intervention study no difference in anthropometric indices between the experimental and control groups was observed. This study suggests the necessity of further effectiveness studies on food fortification in infants.

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6

General Discussion

The results of the research presented in this thesis demonstrated similar levels of micronutrient deficiencies in both rural and urban disadvantaged South African infants. Marked differences were observed in micronutrient deficiencies, linear growth and dietary intake between black and coloured infants in an urban community. These findings highlighted the importance of including the assessment of micronutrient status in addition to measures of weight and length in successfully assessing nutritional status in children from different communities. Results showed that micronutrient deficiencies were present in the absence of signs of linear growth retardation. Inadequate dietary intake mainly due to poor feeding practices induced by either inadequate nutritional knowledge or socio-economic constraints was associated with the micronutrient deficiencies present in these communities. The early cessation of breast feeding and subsequent introduction of complementary food was common.

Poor appetite has been associated with poor dietary intake. Results demonstrated that appetite in these infants at the age of 6 months was adequate. Appetite at the age of 6 months does not yet seem to be affected by the presence of micronutrient deficiencies.

Intervention with a micronutrient-fortified complementary food in 6-12 month old infants was associated with a reduction in the decline of serum retinol and iron concentration from baseline to follow-up in 6-12-month-old infants. No other associations were observed in this age group.

In this chapter the results presented in this thesis will be discussed with reference to changes in nutrition with increasing urbanisation. Nutritional status and feeding practices of low socio-economic rural and urban preschool children will be discussed and compared in the light of the nutrition transition accompanying rapid urbanisation. Linear growth with reference to differences between coloured and black infants will be elucidated. The role of fortification of complementary food will be elaborated on.

Nutrition in transition

Impact on infant nutrition

South Africa experiences rapid urbanisation. Many South Africans leave underdeveloped rural areas in the hope of finding a better life in urban areas. From 1993 to 1996 the percentage of urbanised South Africans increased from 36% to 43%. If this annual urbanisation rate of 2.5% per annum continues, and it is estimated to be higher, it implies that 60% of South Africans will be urbanised by 2001. With an African population of approximately 40 million this implies that about 24 million Africans reside in urban areas

(South African Health Review, 1998). Urbanisation in developing countries is commonly associated with a reduction in infant mortality, infectious disease and an increase in life expectancy and chronic diseases. The infant mortality rate in South Africa has been reduced to 47/1000 live births most likely due to better health care in an increasing urban population (South African Healh Review, 1998). However, urbanisation is not necessarily accompanied by improvement in socio-economic circumstances. It often leads to poverty (Yach *et al.,* 1990; Murray, 1996).

This will influence food accessibility and choices resulting in diets inadequate in essential nutrients (Figure 1). Urbanisation often exposes urban communities to the so-called double burden of disease, which is characterised by malnutrition of children and increased prevalence of non-communicable diseases in adults (Gross *et al.,* 1989). Both urban and rural communities in this study were of low socio-economic status as indicated by low educational level, possession of limited material goods and the type of housing. These indicators were remarkably constant within these groups (Yach *et al.,* 1990).

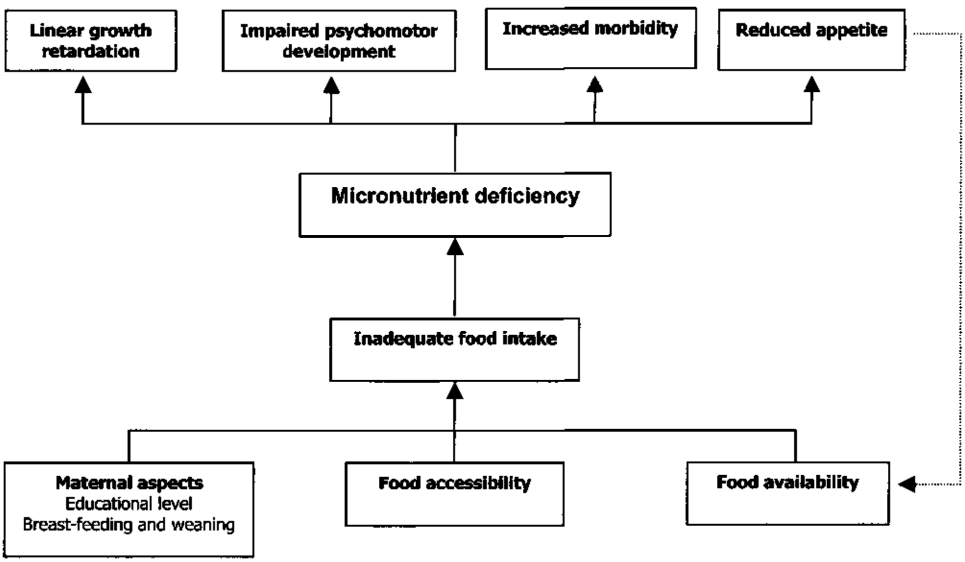

Figure 1 Simplified conceptual framework of causes and consequences of micronutrient deficiencies in preschool children.

Most studies on nutrition transition mention little about changes in infant nutrition with urbanisation. From this study it was clear that although breast-feeding practices and time of weaning differed little between rural and urban infants, great differences exist with regard to complementary feeding (Faber *et al.,* 1997). In the rural areas complementary food was predominantly maize meal as opposed to commercially manufactured infant cereal in the urban areas. On its own maize meal used in the rural areas is high in energy, but insufficient in micronutrients (Faber *et al.,* 1997).

In a survey among five developing countries Gibson *et al.,* (1998) observed that most commonly-used complementary foods, although sufficient in energy, did not supply sufficient dietary zinc and iron. The dominance of maize in the diet of rural infants and the infrequent intake of iron and β-carotene-rich foods may explain the high prevalence of micronutrient deficiency observed in this population. *Imifino,* a locally grown green leafy vegetable of the *Amaranthus spp.* high in both iron and vitamin A, was regularly consumed in the rural community (Harrison *et al.,* 1969). However, some recent studies have shown that a high consumption of dark green leafy vegetables does not necessarily increase the serum concentration of β-carotene (West *et al.,* 1997). Thus the presumably traditional infant diet consumed in rural areas does not seem to effectively address and prevent micronutrient deficiency (Schmidt *et al.,* 1995).

The reported regular consumption of commercially fortified infant cereal in the urban areas differed from the predominantly maize-based diet of rural infants. The consumption of commercially manufactured infant food should at least partially address micronutrient deficiency in these urban infants. However, the majority of infants consumed the porridge in a diluted form. The amount of dry product per serving was small. The intake of micronutrients was thus reduced. The potential contribution of a fortified food to address micronutrient deficiency was limited in this community due to the incorrect use of the cereal.

In both the rural and urban infants the introduction of complementary food coincided with the average age of cessation of breast-feeding at 3 months of age. In the most recent report on infant and young child nutrition of the WHO exclusive breast-feeding till six months is recommended (WHO, 2001). Looking at this recommendation in the light of the results from this study deserves some discussion. The promotion of exclusive breast-feeding till six months in both rural and urban areas where the average age of weaning is three months will need a massive educational approach to change current habits. Adhering to this recommendation may successfully address micronutrient deficiency, but to change breast-feeding and weaning practices may take long, and micronutrient deficiencies need to be addressed sooner.

In addition, this report recommends the utilisation of local nutrient rich foods. In countries where agricultural production and diversity on community level exists and is sustainable this may be possible. In the rural community in our study, agricultural production is limited to a small variety of food of which maize is predominant. It is agreed that this option is important. In this regard research in the same rural area of this study is aimed at developing extended home gardens producing crops rich in vitamin A and iron throughout the year ensuring sustainability. Results of this study will soon be published (Faber *et al.,* in press).

Impact on linear growth retardation

Most often the nutritional situation in rural areas in developing countries is perceived to be worse than that in urban areas (SAVACG, 1999). Using stunting as a proxy of malnutrition there was not much difference between black rural and urban infants studied. In both communities prevalence increased after the age of 12 months to approximately 19% (Kriek, unpublished data). This represents a mild degree of linear growth retardation (De Onis *et al.,* 1993) and compares well with a recent national anthropometric survey of the country (SAVACG, 1999). It also indicates nutritional deficiencies during the preceding months (Brown *et al.,* 1995). One possible explanation for the lack of difference in prevalence of stunting may be the levels of poverty existing in the urban areas included in this study (Menon *et al.,* 2000). In a study by Dewey *et al.* (1992) the comparison between an affluent and poor infant community showed a difference in linear growth after 6 months of age. This difference was not due to a difference in lactation, but to inadequate complementary feeding.

The difference in linear growth between the urban coloured and black infants was obvious. The high prevalence of low birth weight and small maternal height in the coloured community may partially explain the higher prevalence of stunting in this community (Hernandez-Diaz *et al.,* 1999; Doherty *et al.,* 2001; Hautvast *et al.,* 2000; Aider *et al.,* 1999). Some authors may ascribe the difference found in anthropometric results to the inadequacy of the NCHS reference data to be applied to different populations. It has often been noted that this reference should not be applied to children in the developing world. However, although there are limitations to these reference values, all major populations have a similar growth potential. The differences so often observed could largely be due to environmental differences. Nutritional status and exposure and treatment of infectious diseases largely influence linear growth (Ulijaszek, 1994). In populations often reported to have a high prevalence of stunting, growth of high socio-economic preschool children was greater when compared to the NCHS reference data (Droomers *et al.,* 1995; Kelly *et al.,* 1997).

Micronutrient intervention studies among infants in other African countries showed a similar lack of effect on linear growth observed in this study (Lartey *et al.,* 1999; WHO, 1998). However, the low prevalence of stunting in our study population may have been underlying this lack of difference. Linear growth retarded children respond better to nutrition intervention studies. This was demonstrated by a zinc supplementation study of similar duration showing a substantially larger increase in linear growth in a group of stunted infants when compared to non-stunted infants (Umeta *et al.,* 2001).

The advantage of the relatively low prevalence of stunting in both rural and urban communities lies in prevention. If timely efforts are made the detrimental consequences associated with stunting can be prevented. If these causal factors are not addressed stunting may remain for life and these children may have a lower growth trajectory (Martorell *et al.,* 1990; Schroeder *et al.,* 1995).

Addressing micronutrient deficiency

Food fortification

The latest report of the WHO on infant nutrition recommends supplementation, food fortification and dietary diversification to prevent malnutrition (WHO, 2001). One of the most successful examples of food fortification is the fortification of salt with iodine in addressing iodine deficiency. Compulsory iodisation of salt has been implemented in South Africa with a subsequent reduction in the prevalence of low urinary iodine excretion (Jooste *et al.,* 2000). Surveillance of the effectiveness of salt iodisation at household level throughout the country is conducted on a regular basis. The advantage of food fortification is that it is less dependant on health infrastructure, as opposed to supplementation, making it an attractive alternative in developing countries.

Sub-Saharan Africa lags behind Latin America and Asia with respect to food fortification. In close collaboration with The Micronutrient Initiative (MI) and the United Nations Childrens Fund (UNICEF), South Africa is working at designing and implementing a national food fortification strategy (ACC/SCN, 2001). Recently a national food consumption survey in South Africa identified maize, white sugar, tea, whole milk and brown bread as the most commonly used foods. These foods have been identified as potential vehicles for food fortification (Labadarios, 2001). Currently the national fortification of maize meal is in progress with the aim to address malnutrition in preschool children including infants.

However, Hendricks *et al.* (2001) has highlighted the fact that national fortification of maize will not address malnutrition in the urban areas as effectively as in the rural areas, due to the low intake of maize in the cities. This confirms our findings with relation to the consumption of commercially manufactured complementary food. They suggest fortification of wheat flour or sugar to address these problems.

In a study on the effect of food fortification in infants, Lartey *et al.* (2000) observed a positive association between dietary vitamin A intake and serum retinol concentration in their experimental group. An increase in the serum retinol levels was observed in the experimental group. The lesser response of serum retinol concentration observed in our study may be ascribed to a few factors which may have influenced the differences observed. The response to vitamin A fortification may have been greater had the prevalence of vitamin A deficiency in the study sample been greater.

The potential consequence of the difference observed in serum retinol concentration from baseline to follow up between the two groups may contribute to a reduction of morbidity in infants receiving fortified complementary food (Dudley, 1997; Fawzi *et al.,* 1999). It could also contribute positively to the efficacy of immunisation regimes (Bhaskaram *et al.,* 1997).

The type of iron fortificant used in the study presented in this thesis may explain the limited response to increased iron intake through the fortified cereal. Ferric pyrophosphate used in the cereal is less bio-available compared to ferrous fumarate (Davidsson *et al.,* 2000). In a meta-analysis of iron studies short-term iron treatment did not seem to benefit the development of anaemic children younger than 2 years of age. The poorer cognition and school performance observed in older children who were anaemic when young compared to non-anaemic children, emphasises the importance of sufficient serum iron concentration (Grantham McGregor *et al.,* 2001). However, a study introducing a iron fortified formula milk to inner city infants, until the age of 18 months, prevented iron deficiency anaemia and reduced the decline in psychomotor development (Williams *et al.,* 1999)

Other options in addressing micronutrient deficiencies

Apart from food fortification and supplementation other options exist to address nutritional deficiencies. Genetically modified food has become a potential avenue to address nutritional deficiencies on a large scale. Genetic modification implies the identification and insertion from another source, or the deletion of a gene with the purpose to improve a desired trait. In this case it is to optimise micronutrient density. As an example, with respect to information on the genetics of inheritance of carotenoid content, ample information exists with regard to carrots and tomatoes. The major gene for carotene in maize has also been identified. One of the most important findings in this respect has been the production of yellow endosperm transgenic rice grain containing 1.6 µg/g ß-carotene (Ye *et al.,* 2000). This yellow rice has the potential to meet part of the vitamin A requirements of the whole of South Asia. Currently a high iron, high zinc high yielding variety of rice is under way. Although gene technology often receives criticism it holds tremendous promise to address micronutrient deficiency in developing countries where other alternatives are often not as successful or hampered by failing infrastructure.

Although South Africa does not have a food shortage, research is done to increase crop yield (Barnard, 2001). The major contribution to genetically modified food has been focussed on maize and wheat which are the predominant staples of the country. Research has concentrated on disease prevention and resistance to increase crop yield.

Compliance

The difficulties experienced in compliance warrant some discussion. The influence of urbanisation and accompanying migratory patterns of mothers in this population explained some of the difficulties experienced. Many urban dwellers come to the city in the hope of a better life. Antenatal and infant and childcare are specifically sought after. However, these "visiting" mothers are taken up in the clinic records often giving false addresses in fear of being persecuted. Finding and following-up some of these mothers was often unsuccessful due to these reasons. During varying periods after a child has completed its immunisation regime an additional loss of study participants was experienced when mothers moved back to their rural home towns. The above posed tremendous challenges to the research and resulted in lower than expected sample sizes.

General conclusions

The results from the studies presented in this thesis highlighted micronutrient deficiencies in both rural and urban children. Breast-feeding and complementary feeding practices in both rural and urban infants may have contributed to these deficiencies. Low maternal education and low socio-economic status characterised the communities included in this thesis. Both these aspects contribute to malnutrition (Figure 1). The lack of knowledge of infant nutrition was manifested in less optimal food choices for their infants at the age of weaning. This could possibly have resulted in the generally high prevalence of micronutrient deficiency observed. The lack of severe linear growth retardation in this age group masked the underlying micronutrient deficiencies. However, it is known that the levels of stunting increase after the age of 12 months in this and other similar communities, a clear sign of past nutritional deficiencies. This emphasises the importance of addressing nutritional deficiencies during infancy.

Appetite does not seem to be affected by the nutritional deficiencies at the age of 6 months. This finding may have important implications for the development and introduction of complementary food at this age.

The potential effect of a fortified complementary food on vitamin A and iron status should be investigated further. The lessons learnt with respect to compliance may aid other investigators conducting nutrition research in similar communities.

From the literature it is clear that low socio-economic communities are the most vulnerable to micronutrient deficiencies and its grave consequences. To address these socio-economic issues lies not primarily with health workers. Governments are predominantly responsible. However, it would be futile to wait for government programmes to address these issues. From a health perspective one needs to find ways to address these health issues irrespective of continued socio-economic difficulties. However, reducing poverty and improving access to adequate diets should remain an important goal of programmes designed to improve the nutritional status of undernourished populations (Fawzi *et al.,* 1997).

Policy implications

The South African government has formed a national fortification task team in an effort to address food fortification to improve the nutritional status of vulnerable groups (Food and Beverage Processing Programme, 1999). However, little attention was given to food consumption in infants less than 12 months old. The results of this study clearly show that there are differences in food consumption patterns between rural and urban infants. The work by Hendricks *et al.* (2001) on the feasibility of fortification of maize, wheat and sugar contributes greatly to assist government and industry to approach the issue of food fortification effectively. They also highlight the difference in food consumption between rural and urban populations and suggest the fortification of wheat flour to address urban food consumption patterns. The results of the studies presented in this thesis should aid government in the development of fortified cereals to address both rural and urban infants. The finding with respect to the adequacy of the appetite at the age of 6 months has important implications with respect to micronutrient and energy density of fortified products for this age group.

The use of commercially manufactured fortified infant foods in urban infants has implications for national food fortification initiatives. To change the common use of these products in urban areas would take a tremendous effort. Nutrition education programmes would need to incorporate suggested changes in the food consumption practices of urban infants. Alternatively government and industry could cooperate to optimise the benefit of these products. This should be done with special reference to optimise fortification and bio-availibility.

Future research

Inadequate food intake, whether through lack of food availability, accessibility or reduced appetite, could potentially be addressed through three basic pathways: food supplementation, fortification and dietary diversification. Of course greater issues like poverty alleviation, improved immunisation coverage, reduction in morbidity and nutrition and health education would all contribute to improve adequate dietary intake and thus reduce malnutrition. Many successful studies have been performed, all proving the efficacy of supplementing with specific micronutrients in reducing malnutrition. More research is still needed on a variety of issues such as:

1. Large studies evaluating the effectiveness of fortified complementary food in infants from 6 to 12 months on growth and psychomotor development up to the age of 24 months.
2. Studies assessing the incidence of HIV infection and tuberculosis and its effect on nutrition, growth and development of infants.
3. Ways of improving quality of life in infants on community level infected with HIV through optimal nutrition.
4. Studies evaluating the quality of breast milk in mothers with infants aged 3 and 6 months from poor urban communities to establish whether breast milk alone would be sufficient for infants to the age of 6 months.
5. Studies finding ways to improve maternal nutritional knowledge with the aim of improving infant nutrition.
6. Efficacy and effectiveness on infant growth and development of local production of vitamin A- and iron-rich food should be tested.

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Summary

With increasing urbanisation differences in rural and urban infant nutrition and its effect on nutritional status, growth and development need special attention. The early introduction of complementary food at the average age of 3 months in South African rural and urban populations is of concern. Early introduction of complementary food has been associated with micronutrient deficiency and the onset of linear growth retardation. Urban infants predominantly consume commercially manufactured complementary food as opposed to the use of traditional maize as complementary food in rural infants.

This thesis comprise four studies. The first two studies describe the micronutrient status with specific reference to serum retinol, iron and zinc concentration and urinary iodine concentration. In addition linear growth, food intake and breast feeding and complementary feeding practices were studied. The third study assessed the adequacy of the appetite of urban disadvantaged infants at the age of 6 months. The final study consisted of an intervention study examining the effect of a micronutrient fortified complementary food on the micronutrient status, growth and development of urban black infants aged 6-12 months.

The first study (***Chapter 2***) deals with the assessment of the nutritional status of rural pre-and primary school children to establish the extent of micronutrient deficiency and linear growth retardation. From a rural community in KwaZulu Natal, a north-eastern province of South Africa, a random sample of 105 pre-school and 131 primary school children was selected. Micronutrient status was assessed from blood samples collected. Anthropometric measurements included weight and length. Dietary data was collected using a food frequency questionnaire. Marginal vitamin A deficiency was present among 45%, anaemia among 24% and iron deficiency among 20% of pre-school children. Moderate iodine deficiency was observed in 32% and severe deficiency in 9% of pre-school children.

In rural pre-school children, deficiencies in serum retinol, iron and urinary iodine were present in the absence of marked linear growth retardation.

Chapter 3 describes a study establishing the extent of micronutrient deficiencies and linear growth retardation in urban black and coloured infants. For this study a sample of 60 black and 60 coloured infants aged 6-12 months were randomly selected from two urban communities in the western Cape, South Africa. Micronutrient status was assessed from blood samples. Anthropometric measurements included weight and recumbant length. Dietary intake was assessed by 24 hour dietary recall.

Linear growth retardation was detected in 18% of coloured infants compared to 8% in black infants. Low birth weight (<2500g) was present in 27% of coloured infants. The prevalence of anaemia was high in both coloured (64%) and black (83%) infants. Iron

deficiency was present in 32% of coloured and 46% of black infants. Plasma zinc concentrations indicated a zinc deficiency prevalence of 35% and 33% in the coloured and black infants, respectively. The prevalence of marginal vitamin A deficiency was considerably higher in the black (23%) compared to the coloured (2%) infants. The average daily energy intake of the black infants was lower than that of the coloured infants and the diet deficient in vitamin A, iron and zinc.

The results from this study show that high levels of micronutrient deficiencies exist in urban coloured and black infants. Absence of marked linear growth retardation in the black opposed to the coloured infants emphasises the importance of including micronutrient status assessment in nutrition studies among infant populations.

The aim of ***chapter 4*** was to assess the adequacy of the appetite at the age of 6 months in black urban infants. A random sample of 50 infants was selected from those attending the local clinic. Biochemical analyses of blood serum retinol, iron and zinc concentration determined micronutrient status. Anthropometric measurements included weight, recumbent length as well as knee-heel length. The ad-libitum consumption test was used to assess appetite. A commonly consumed commercial complementary food was used as test porridge. Preperation procedures were standardised. Daily energy intake was assessed by 24h dietary recall on the same day as the appetite test. For each child the appetite tests and the 24h dietary recall was done in triplicate.

The average energy intake from the appetite test was 312±182kJ and the average daily energy intake as measured by 24h dietary recall was 3326±767kJ. In this study the appetite test was a reproducible test of infant food intake. However, there was no association observed between the average daily energy intake and average energy intake from the appetite test. No significant association was observed between average energy intake from the appetite test and serum vitamin A, iron and zinc concentrations. None of the anthropometric indicators showed any association with average energy from the appetite test. Surprisingly, there was no difference in energy intake from the appetite test between breast fed and non-breast fed infants.

The results from this study show that the appetite of urban disadvantaged infants was adequate at the age of 6 months. Micronutrients did not seem to have affected appetite negatively in this age group. This has particular relevance in considering an appropriate complementary food in nutrition intervention studies in infants in this age group.

Chapter 5 describes the effect of a micronutrient fortified complementary food on the nutritional status, growth and development of 6-12 month old urban black infants. Sixty infants were randomly selected from an urban black community in the western Cape, South Africa. Infants were randomly allocated to either an experimental or a control group. Infants in the experimental group received a micronutrient fortified complementary food for a period of six months. The control group continued to consume its usual diet. Micronutrient status at beginning and end of study was assessed from blood samples. Body weight and recumbent length were assessed at baseline and after six months. The Denver Developmental Screening (DDST) test was used to assess mental and motor development.

The decline in serum retinol from 6 to 12 months old was reduced in the experimental compared to the control group, resulting in significantly higher serum retinol concentration in the experimental (26.8±5.8) compared to the control group (21.4±5.7) after six months. A similar but less marked trend was observed for serum iron concentration. No difference was observed in hemoglobin and zinc concentrations after 6 months. Weight gain over the 6 month period did not differ significantly between infants in the experimental (2.1±0.9kg) and control group (2.1±1.2). Also, there was no difference in linear growth over the same period between the experimental (10.0±1.5cm) and the control (10.1±2.1) group. No difference was observed between the two groups in psychomotor developmental scores after six months intervention.

Introducing a micronutrient fortified complementary food in the diet of 6-12 months old infants seemed to reduce the decline in serum retinol and serum iron concentration observed over the 6 month follow up period. No benefit was observed in serum zinc, hemoglobin, weight, linear growth and psychomotor developmental outcome.

In ***chapter 6*** we discuss the results presented in this thesis with special reference to the influence of urbanisation on infant nutrition and the potential of food fortification to address micronutrient deficiencies in infants.

The prevalence of stunting in South African infants does not compare with the high prevalence observed in neighbouring African countries. However, the prevalence of deficiencies in serum retinol, iron and zinc concentration in this age group was high. These deficiencies were observed in both rural and urban communities. The use of different complementary food in rural and urban infants has implications for national food fortification initiatives. The finding that the appetite of infants at the age of 6 months was adequate has direct implications for the design of nutrition intervention studies with specific reference to the composition of a fortified complementary food.

Samevatting

Met toenemende verstedeliking behoort die verskille in voeding tussen landelike en stedelike jong kinders meer aandag te geniet, veral die invloed wat dit op voedingstatus, groei en ontwikkeling het. Die vroeë blootstelling aan komplementêre voeding in Suid-Afrikaane suigelinge in die besonder is kommerwekkend. Vroeë blootstelling aan komplementêre voeding is al geassosieer met die oorsprong van liniêre groeivertraging. Die stedelike kinders is veral geneig om kommersieel vervaardigde komplementêre voedsels te eet en dit word meesal nie in korrekte hoeveelhede ingeneem nie.

Hierdie tesis beskryf vier studies. Die eerste twee studies beskryf die mikronutriënt status van voorskoolse kinders. Daar word spesifiek verwys na serum retinol, yster, sink en urinêre jodium status. Liniêre groei, voedsel inname en borsvoeding en komplementêre voeding is ook bestudeer. Die derde studie het die genoegsaamheid van die aptyt van 6 maande oue kinders bepaal. Die finale studie was 'n intervensie studie wat die effek van 'n mikronutriënt-gefortifiseerde komplementêre voeding op die mikronutriënt status, groei en ontwikkeling van stedelike swart kinders tussen die ouderdomme van 6-12 maande bestudeer het.

Die eerste studie (Hoofstuk 2) handel oor die bepaling van die voedingstatus van plattelandse voor- en laerskool-kinders om die omvang van mikronutriënt gebreke en liniêre groeivertraging vas te stel. 'n Steekproef van 105 voor- en 131 laerskool-kinders is van 'n plattelandse gemeenskap in KwaZulu-Natal, 'n provinsie in die noord-ooste van die land, getrek. Bloedmonsters is geanaliseer om die mikronutriënt status te bepaal. Dieet data is ingesamel by wyse van voedsel frekwensie vraelyste. Matige vitamien A-gebrek was teenwoordig in 45%, anemie in 24% en ystergebrek in 20% van voorskoolse kinders. Matige jodiumgebrek was teenwoordig in 32% en erge gebrek in 9% van voorskoolse kinders.

Serum retinol, yster en jodiumgebrek was teenwoordig in voorskoolse kinders in hierdie plattelandse gemeenskap in die afwesigheid van merkbare liniêre groeivertraging.

Hoofstuk 3 beskryf 'n studie waar die omvang van mikronutriënt gebreke en liniêre groeivertraging in stedelike swart en kleurling kinders bepaal is. 'n Steekproef van 60 swart en 60 kleurling kinders tussen die ouderdom van 6 en 12 maande is van twee stedelike gemeenskappe in die Wes-Kaap, Suid-Afrika getrek. Mikronutriënt status is vanaf bloedmonsters bepaal. Antropometriese metinge het liggaamsmassa en lengte ingesluit. Dieet inname is by wyse van die 24 uur dieet herroep metode ingesamel.

Liniêre groeivertraging is in 18% van kleuring en 8% van swart kinders waargeneem. Die voorkoms van lae geboorte gewig (<2500 g) was 27% in die kleurling gemeenskap. Die voorkoms van anemie was hoog in beide die kleurling (64%) en swart (83%) gemeenskappe. Ystergebrek was teenwoordig in 32% van kleurling en 46% van swart kinders. Plasma sink konsentrasie het op 'n sinkgebrek van 35% by kleurling en 33% by swart kinders gedui. Die voorkoms van matige vitamien-A gebrek was aansienlik hoër in die swart (23%) as die kleurling (2%) kinders. Die gemiddelde daaglikse energie inname van swart kinders was laer as die van die kleurling kinders. Die daaglikse inname van vitamien A, yster en sink was ook laer in die swart kinders.

Hierdie resultate toon dat daar 'n hoe voorkoms van mikronutriënt gebreke in hierdie stedelike swart en kleurling kinders bestaan. Die afwesigheid van merkbare liniêre groeivertraging in die swart vergeleke met die kleurling kinders benadruk die belangrikheid van die insluiting van mikronutriënt status bepaling in voedingstudies in kinders.

Die doelwit van die studie wat in Hoofstuk 4 bespreek word, was om die aptyt 6 maande oue kinders te bepaal en vas te stel of dit voldoende is vir kinders van die ouderdom. Mikronutriënt status is bepaal deur die analise van bloedmonsters vir serum retinol, yster en sink. Antropometriese metinge het liggaamsmassa, lengte en onderbeen lengte ingesluit. Die *ad-libitum* konsumpsie toets is gebruik om die aptyt te bepaal. 'n Algemeen aanvaarde kommersieel vervaardigde komplementêre voedsel is as toetspap gebruik. Voorbereidingsprosedures is gestandaardiseer. Daaglikse energie inname is bepaal met behulp van die 24-uur dieet herroep. Die prosedure is op dieselfde dag as die aptyt toets uitgevoer. Die aptyt toets en die 24-uur dieet herroep is op drie verskillende dae op elke kind herhaal.

Die gemiddelde energie inname tydens die aptyt toets was 312±182 kJ. Die daaglikse energie inname was gemiddeld 3326±767 kJ. In hierdie tesis is die aptyt toets bevind as 'n reproduseerbare metode om voedsel inname in jong kinders te bepaal. Daar was egter geen betekenisvolle verband tussen die energie inname van die aptyt toets en die daaglikse energie inname nie. Geen verband is ook waargeneem tussen die energie inname van die aptyt toets en serum retinol, yster en sink nie. Geen van die antropometriese metinge het enige betekenisvolle verband met die energie inname van die aptyt toets getoon nie. Daar was geen betekenisvolle verskil tussen energie inname tydens die aptyt toets tussen borsgevoede kinders en kinders wat nie meer bors gevoed is nie.

Die resultate van hierdie studie wys dat die aptyt van stedelike swart agtergeblewe kinders genoegsaam is op die ouderdom van 6 maande. Mikronutriënt status het geen betekenisvolle effek op aptyt gehad in hierdie groep kinders nie. Hierdie bevindinge het besondere implikasies in die keuse van 'n geskikte komplementêre voedsel vir voedingsintervensie studies in hierdie ouderdomsgroep.

Hoofstuk 5 beskryf die effek van 'n mikronutriënt gefortifiseerde komplementêre voedsel op die voedingstatus, groei en ontwikkeling van 6-12-maande oue swart stedelike kinders. Sestig kinders vanaf die ouderdom van 6 tot 12 maande is ewekansig gekies uit 'n stedelike swart gemeenskap in die Wes-Kaap, Suid-Afrika. Kinders is ewekansig toegewys aan 'n eksperimentele of kontrole groep. Kinders in die eksperimentele groep het 'n mikronutriënt gefortifiseerde komplementêre voedsel ontvang vir 'n periode van ses maande. Die kontrole groep het voortgegaan om hulle gebruiklike dieet te volg. Mikronutriënt status is aan die begin en einde van die studie by wyse van biochemiese analise van bloedmonsters gedoen. Liggaamsmassa en lengte is ook tydens basislyn en weer aan die einde van die studie op 12 maande bepaal. Die "Denver Developmental Screening Test" (DDST) is gebruik om verstandelike en motoriese ontwikkeling te bepaal.

Die afname in serum retinol vanaf 6 tot 12 maande oue kinders was minder in die eksperimentele vergeleke met die kontrole groep. Dit het 'n betekenisvolle hoër gemiddelde serum retinol vlak in die eksperimentele groep (26.8±5.8 μg/dL) vergeleke met die kontrole groep (21.4±5.7 μg/dL) tot gevolg gehad. 'n Soortgelyke maar minder merkbare neiging was sigbaar met serum yster konsentrasie. Geen verskil tussen groepe was sigbaar met betrekking tot hemoglobien en serum sink konsentrasie na ses maande nie. Gewigstoename oor die ses maande periode het nie betekenisvol verskil tussen die eksperimentele (2.1±0.9 kg) en die kontrole groep (2.1±1.2 kg) nie. Daar was ook geen betekenisvolle verskil in liniêre groei oor die intervensie periode tussen die eksperimetele (10.0±1.5 cm) en die kontrole groep (10.1±2.1 cm) nie. Geen verskil is waargeneem in psigomotoriese toets resultate tussen die twee groepe na die intervensie periode nie.

Die byvoeging van 'n mikronutriënt gefortifiseerde komplementêre voedsel in die dieet van 6-12-maande oue kinders het geblyk die afname in serum retinol en serum yster gedeeltelik te verminder in die eksperimentele groep in vergelyking met die kontrole groep oor die ses maande intervensie periode. Geen voordeel is waargeneem ten opsigte van die uitkomste van serum sink, hemoglobien, liggaamsmassa, liniêre groei en psigomotoriese ontwikkeling nie.

In Hoofstuk 6 word die resultate van hierdie proefskrif bespreek met spesiale verwysing na die invloed van verstedeliking op kindervoeding en die potensiaal wat voedsel fortifisering inhou om mikronutriëntgebreke in jong kinders aan te spreek.

Die voorkoms van liniêre groeivertraging in Suid-Afrikaanse kinders vergelyk nie met die hoë voorkoms wat in naburige Afrika lande waargeneem is nie. Nogtans is die voorkoms van mikronutriëntgebreke in Suid-Afrikaanse jong kinders hoog. Hierdie mikronutriëntgebreke is in beide landelike sowel as stedelike kinders waargeneem. Die gebruik van verskillende komplementêre voedsels in landelike en stedelike kinders het belangrike implikasies vir nasionale voedsel fortifiseringsinisiatiewe. Die bevinding dat die aptyt van 6-maande oue kinders genoegsaam blyk te wees het belangrike implikasies vir die ontwerp en beplanning van voedingsintervensie studies in jong kinders, veral met betrekking tot die samestelling van so 'n voedsel.

Samenvatting

Vanwege de toenemende verstedelijking vragen verschillen in zuigelingenvoeding tussen stedelijke en landelijke gebieden en het effect daarvan op de voedingsstatus, groei en ontwikkeling, speciale aandacht. Het vroegtijdig introduceren van bijvoeding op de gemiddelde leeftijd van drie maanden in Zuid-Afrikaanse bevolkingsgroepen in stedelijke en landelijke gebieden leidt tot bezorgdheid. Het vroegtijdig introduceren van bijvoeding is geassocieerd met micronutriëntendeficiënties en het ontstaan van een achterstand in lengtegroei. Zuigelingen in stedelijke gebieden consumeren hoofdzakelijk commercieel gefabriceerde bijvoeding in tegenstelling tot het gebruik van de traditionele maïs als bijvoeding voor zuigelingen in landelijke gebieden.

Dit proefschrift bestaat uit vier studies. De eerste twee studies beschrijven de micronutriëntenstatus, vooral met betrekking tot retinol-, ijzer- en zinkconcentraties in serum en de jodiumconcentratie in urine. Daarnaast werden lengtegroei, voedingsinname en de toepassing van borstvoeding en bijvoeding bestudeerd. De derde studie bepaalde of de eetlust van zuigelingen van zes maanden oud uit stedelijke achterstandsgebieden voldoende was. De laatste studie bestond uit een interventie met als doel het effect te onderzoeken van een met micronutriënten verrijkte voeding op de micronutriëntenstatus, groei en ontwikkeling van zwarte zuigelingen in de leeftijd van 6 tot 12 maanden uit stedelijke gebieden.

De eerste studie (hoofdstuk twee) heeft betrekking op het bepalen van de voedingsstatus van peuters, kleuters en basisschoolkinderen uit landelijke gebieden om de mate van micronutriëntendeficiëntie en achterstand in lengtegroei vast te stellen. Uit een bevolkingsgroep in een landelijk gebied in KwaZulu Natal, een Noord-Oostelijke provincie van Zuid-Afrika, werd een willekeurige steekproef getrokken van 105 peuters en kleuters (0.5 tot 6 jaar) en 131 basisschoolkinderen (6 tot 11 jaar). Bloedmonsters werden verzameld om de micronutriëntenstatus te bepalen. Gewicht en lengte werden gemeten en voedingsinformatie werd verzameld met behulp van een voedselfrequentievragenlijst. Marginale vitamine-A-deficiëntie was aanwezig bij 45%, anemie bij 24% en ijzerdeficiëntie bij 20% van de peuters en kleuters. Milde jodiumdeficiëntie werd waargenomen bij 32% en ernstige jodiumdeficiëntie bij 9% van de peuters en kleuters.

Bij peuters en kleuters uit landelijke gebieden waren deficiënties in retinol en ijzer in serum en jodium in urine aanwezig zonder dat er een opvallende achterstand in lengtegroei was.

Hoofdstuk drie beschrijft een studie om de mate van micronutriëntendeficiënties en achterstand in lengtegroei vast te stellen bij zwarte en kleurling zuigelingen uit stedelijke gebieden. Voor deze studie werd een willekeurige steekproef getrokken van 60 zwarte en 60 kleurling zuigelingen van 6 tot 12 maanden oud, uit twee stedelijke wijken in de

Westkaap van Zuid-Afrika. De micronutriëntenstatus werd bepaald met behulp van bloedmonsters. Het gewicht werd bepaald, evenals de lengte in liggende positie. De voedingsinname werd bepaald met behulp van de 24-uurs navraagmethode.

Achterstand in lengtegroei werd gevonden bij 18% van de kleurling zuigelingen in vergelijking met 8% bij de zwarte zuigelingen. Een laag geboortegewicht (<2500g) was aanwezig bij 27% van de kleurling zuigelingen. De prevalentie van anemie was hoog bij zowel kleurling (64%) als zwarte (83%) zuigelingen. IJzerdeficiëntie was aanwezig bij 32% van de kleurling en bij 46% van de zwarte zuigelingen. De zinkconcentraties in plasma duidden op een prevalentie van zinkdeficiëntie van respectievelijk 35% en 33% bij de kleurling en zwarte zuigelingen. De prevalentie van marginale vitamine-A-deficiëntie was aanzienlijk hoger bij de zwarte zuigelingen (23%) in vergelijking met de kleurlingen (2%). De gemiddelde dagelijkse voedingsinname van de zwarte zuigelingen was lager in energie dan die van de kleurling zuigelingen en de voeding was deficiënt in vitamine A, ijzer en zink.

De resultaten van deze studie laten zien dat micronutriëntendeficiënties in hoge mate voorkomen bij zwarte en kleurling zuigelingen uit stedelijke gebieden. De afwezigheid van een opvallende achterstand in lengtegroei bij zwarte zuigelingen in tegenstelling tot bij kleurlingen benadrukt het belang van het bepalen van de micronutriëntenstatus bij voedingsstudies onder zuigelingenpopulaties.

Het doel van hoofdstuk vier was bepalen of de eetlust bij zwarte zuigelingen van zes maanden uit stedelijke gebieden voldoende was. Uit bezoekers van de lokale kliniek werd een willekeurige steekproef van 50 zuigelingen getrokken. De micronutriëntenstatus werd bepaald door middel van biochemische analyse van bloedserum op retinol-, ijzer- en zinkconcentraties. Gewicht, lengte in liggende positie en de afstand van knie tot hiel werden gemeten. De eetlust werd vastgesteld met behulp van de ad-libitum-consumptie-test waarbij een algemeen geconsumeerde, commerciële bijvoeding als testpap werd gebruikt. Bereidingsmethoden waren gestandaardiseerd. De dagelijkse energie-inname werd bepaald met behulp van de 24-uurs navraagmethode op dezelfde dag als de eetlust-test. De eetlust-test en 24-uurs navraagmethode werden voor elk kind gedaan in triplo.

De gemiddelde energie-inname volgens de eetlust-test was 312 ± 182 kJ en de gemiddelde dagelijkse energie-inname gemeten met de 24-uurs navraagmethode was 3326 ± 767 kJ. In deze studie was de eetlust-test een reproduceerbare test voor de voedingsinname van zuigelingen. Er werd echter geen associatie waargenomen tussen de gemiddelde dagelijkse energie-inname en gemiddelde energie-inname volgens de eetlust-test. Er werd geen significante associatie waargenomen tussen de gemiddelde energie-inname volgens de eetlust-test en vitamine-A-, ijzer- en zinkconcentraties in serum. Geen van de anthropometrische indicatoren liet een associatie zien met gemiddelde energie-inname volgens de eetlust-test. Verwonderlijk was dat er geen verschil was tussen borstgevoede en niet borstgevoede zuigelingen met betrekking tot energie-inname volgens de eetlust-test.

De resultaten van deze studie laten zien dat de eetlust van zuigelingen op de leeftijd van zes maanden uit stedelijke achterstandsgebieden voldoende was. Micronutriënten lijken de eetlust niet negatief te hebben beïnvloed in deze leeftijdsgroep. Dit is vooral van belang bij het samenstellen van een geschikte bijvoeding voor voedingsinterventiestudies onder zuigelingen in deze leeftijdsgroep.

Hoofdstuk vijf beschrijft het effect van een met micronutriënten verrijkte bijvoeding op de voedingsstatus, groei en ontwikkeling van 6 tot 12 maanden oude, zwarte zuigelingen uit een stedelijke gebied. Zestig zuigelingen van zes maanden oud werden willekeurig geselecteerd uit een zwarte wijk in een stedelijk gebied in de Westkaap van Zuid-Afrika. De zuigelingen werden willekeurig toegewezen aan een experimentele groep of aan een controlegroep. De zuigelingen in de experimentele groep kregen voor een periode van zes maanden een met micronutriënten verrijkte bijvoeding. De controlegroep bleef de gebruikelijke voeding consumeren. De micronutriëntenstatus aan het begin en aan het eind van de studie werd bepaald met behulp van bloedmonsters. Lichaamsgewicht en lengte in liggende positie werden gemeten aan het begin van de studie en na zes maanden. De Denver Developmental Screening Test (DDST) werd gebruikt om de mentale en motorische ontwikkeling te bepalen.

De serum-retinolconcentratie in de experimentele groep nam minder af dan in de controlegroep, resulterend in een significante hogere serum-retinolconcentratie in de experimentele groep (26.8 ± 5.8) in vergelijking met de controlegroep (21.4 ± 5.7) na zes maanden. Een vergelijkbare, maar minder duidelijke trend werd waargenomen voor de serum-ijzerconcentraties. Geen verschil werd waargenomen voor de hemoglobine- en zinkconcentraties na zes maanden. Gewichtstoename over de periode van zes maanden was niet significant verschillend tussen de zuigelingen van de experimentele groep (2.1 ± 0.9) en de controlegroep (2.1 ± 1.2). Ook was er geen verschil in lengtegroei over dezelfde periode tussen de experimentele groep (10.0 ± 1.5) en de controlegroep (10.0 ± 2.1). Er werd geen verschil in scores waargenomen tussen de twee groepen na de zesmaandse interventie met betrekking tot psychomotorische ontwikkeling.

Het introduceren van een met micronutriënten verrijkte bijvoeding in de voeding van 6 tot 12 maanden oude zuigelingen leek de afname van retinol- en ijzerconcentraties in serum te verminderen over de zesmaandse periode waarin de zuigelingen gevolgd werden. Er werd geen verbetering waargenomen op de zink- en hemoglobineconcentraties in serum, gewicht, lengtegroei en psychomotorische ontwikkeling.

In hoofdstuk zes worden de in dit proefschrift gepresenteerde resultaten bediscussieerd met speciale aandacht voor de invloed van urbanisatie op zuigelingenvoeding en voedselverrijking als mogelijkheid om micronutriëntentekorten bij zuigelingen aan te pakken.

De prevalentie van 'stunting' (het achterblijven van lengte bij een bepaalde leeftijd) bij Zuid-Afrikaanse zuigelingen valt in het niet bij de hoge prevalentie in naburige Afrikaanse landen. De prevalentie van deficiënties van retinol, ijzer en zink in serum in deze leeftijdsgroep was echter hoog. Deze deficiënties werden zowel in landelijke als in stedelijke gebieden waargenomen. Het gebruik van verschillende bijvoedingen bij kinderen uit landelijke en stedelijke gebieden heeft implicaties voor nationale voedselverrijkingsinitiatieven. Het gegeven dat de eetlust van zuigelingen van zes maanden voldoende was, heeft directe gevolgen voor de opzet van voedingsinterventiestudies met speciale aandacht voor de samenstelling van verrijkte bijvoeding.

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About the author

André Oelofse was born on 18 October 1962 in Mossel Bay, South Africa. After matriculating he commenced his studies at the University of Stellenbosch and obtained the Bachelor of Science (BSc) degree. After his studies he enrolled for two years compulsory military service during which time he served as a medical officer. During his second year of military service he continued his studies part-time and completed his Bachelors Honours (BSc Hons) degree in Nutritional Physiology at the University of Potchefstroom with Prof Esté Vorster. After his military service he spent one year as co-worker in the Department of Zoology at the same university working on the compilation of an atlas on medically important parasites and venomous animals in sub-Saharan Africa. In 1989 he was employed by the South African Medical Research Council in Cape Town. In 1994 he spent three months at the South East Asian Medical Offices (SEAMEO) in Jakarta Indonesia, under the supervision of Dr Werner Schultink co-operating in a research project on iodine deficiency in Malang, East Java. In 1996 he completed his Master of Science (MSc) degree in Human Physiology part-time at the University of Stellenbosch. His thesis dealt with the lipid and lipoprotein epidemiology of black South Africans. In 1997 he received a PhD fellowship from the Division of Human Nutrition and Epidemiology at Wageningen University, The Netherlands, culminating in this thesis.

He served as chairman of the western Cape branch of The Nutrition Society of South Africa for four years and on the organising and scientific committee of the biennial South African Nutrition congress held in Cape Town in 1996. He also served on the organising committee of the IUNS/ILSI Regional Workshop on Urban Nutrition held in Durban, South Africa in 1999, and on the organising committee for the PhD study tour of Wageningen University to South Africa in 1999.

He is married to Izette, a food consultant, and they have two children, Alexander (7) and Isabella (5).

List of Publications

1. Steyn K, Jooste PL, Bourne LT, Fourie J, Badenhorst CJ, Bourne DE, Langenhoven ML, Lombard CJ, Truter H, Katzenellenbogen J, Marais M, Oelofse A. Risk factors for coronary heart disease in the black population of the Cape Peninsula. The BRISK study. S Afr Med J 1991; 79: 480-484.

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