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THE IMPACT OF PAST AND PRESENT ENERGY, MACRONUTRIENT AND MICRONUTRIENT INTAKE ON THE INCIDENCE OF DENTAL CARIES AMONG 5-YEAR-OLD URBAN BLACK SOUTH AFRICAN CHILDREN

JENNIFER MARGARET MACKEOWN

A thesis submitted to the Faculty of Health Sciences, University of the Witwatersrand, in fulfilment of the requirements for the degree

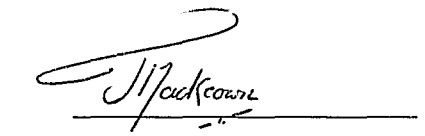
of

Doctor of Philosophy

Johannesburg, 1999

DECLARATION

I, Jennifer Margaret MacKeown declare that this thesis is my own work and has not been presented for any degree of another university.



5th day of August 1999

The work reported in this thesis was performed in the Dental Research Institute of the South African Medical Research Council and the University of the Witwatersrand, Johannesburg.

DEDICATION

The guidance, encouragement, expert knowledge, dedication and enthusiasm of Professor Peter Cleaton-Jones will always be remembered with sincere gratitude.

PUBLICATIONS AND CONGRESS PAPERS DERIVED FROM MATERIAL IN THIS THESIS

PUBLICATIONS

MacKeown JM, Cleaton-Jones PE, Perdrau GG. Energy and macronutrient intake of one-year old South African urban children: The Birth-To-Ten (BTT) Study. Paediatr Perinatal Epidemiol 1996; 10: 150-160.

MacKeown JM, Cleaton-Jones PE, Edwards AW, Turgeon O'Brien H. Energy macro- and micronutrient intake of 5-year-old urban black South African children in 1984 and 1995 Paedtr Perinatal Epidemiol 1998; 12: 297-312.

MacKeown JM, Cleaton-Jones PE, Edwards AW. Energy and macronutrient in relation to dental caries incidence in urban black South African children in 1991 and 1995: The Birth-To-Ten (BTT) Study. Public Health Nutr (Submitted)

CONGRESS PRESENTATIONS

1. *Third Sugar and Health Symposium, Durban 23-24th May 1988.* MacKeown JM. "Diets in selected populations of South Africa".

2. *XXIII Scientific Congress - International Association for Dental Research South African Division, Pretoria 13-15th September 1989.* MacKeown JM. Macronutrient intakes among rural and urban blacks using two assessment methods.

3. *MRC/Wits Birth-to-Ten Project Seminar: Methods and findings of the first year (1991). Marie Curie Lecture Theatre, Wits Medical School 3rd March 1993.* MacKeown JM, Cleaton-Jones PE. Dietary intake of 1-year-olds - methods and findings.

4. *MRC/Wits Birth-to-Ten Project Seminar: Report back of initial findings of 1-year-olds (1991). Funda Centre, Soweto 13th March 1993.* MacKeown JM, Cleaton-Jones PE. Dietary intake of 1-year-olds - initial findings.

5. *Seminar on urbanization for MSc (Community Paediatrics) students. Division of Community Paediatrics, Johannesburg Hospital 14th May 1993.* MacKeown JM. Nutritional intake of 1-year-old urban South African children from the Birth-to-Ten study.

6. *"Interact" - Nutrition Congress 1994. Fifteenth Biennial Congress of the Nutrition Society of Southern Africa and the Third Biennial Congress of the Association for*

Dietetics in Southern Africa. Royal Hotel, Durban 22-26th August 1994. MacKeown JM, Cleaton-Jones PE, Pedrau GG. The Birth-to-Ten Study (BTT). Energy and macronutrient intake of 1- year-old South African children.

7. *XXIX Scientific Congress - International Association for Dental Research South African Division, Cape Town 6-8th September 1995.* MacKeown JM. Birth-to-Ten (BTT) study: The prudent diet and macronutrient intake.

8. *"Hands On" Nutrition Congress 1996. Sixteenth Biennial Congress of the Nutrition Society of Southern Africa and the Fourth Biennial Congress of the Association for Dietetics in Southern Africa, Stellenbosch University, Stellenbosch 31st March - 4th April 1996.* MacKeown JM, Cleaton Jones PE, Edwards AW. Energy and macronutrient intake of 5-year-old urban black South African children: 1984, 1995.

9. *XXX Scientific Congress - International Association for Dental Research South African Division, Johannesburg 4-6th September 1996.* MacKeown JM, Cleaton-Jones PE, Turgeon-O'Brien H. Macro- and micronutrient intake of preschool urban South African children: Birth-to-Ten (BTT) study.

10. *First Joint Congress of the South African Division and the East and Southern Africa Section of the International Association for Dental Research, Cape Town 5-7th October 1997.* MacKeown JM, Cleaton-Jones PE, Edwards AW. Macronutrients, dental caries in urban black children, 1991 and 1995.

11. *"Nutrition in the News" Congress 1998. Seventeenth Biennial Congress of the Nutrition Society of Southern Africa and the Fifth Biennial Congress of the Association for Dietetics in Southern Africa, Sun City 25-29th May 1998.* MacKeown JM, Cleaton-Jones PE, Turgeon-O'Brien. Micronutrient intake of 5-year-old urban black South African children in 1984 and 1995.

12. Guest speaker at *Nutrition in Practice Kelloggs Breakfast Symposia in Johannesburg (5th October 1998), Durban (8th October 1998) and Cape Town (9th October 1998).* MacKeown JM. The nutrient intake of South African preschool children from research results of the Birth-to-Ten (BTT) study.

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ABSTRACT

There is a general agreement that food habits change over time. This has been clearly shown in studies conducted in first world countries, but until recently this information has been lacking in South Africa, particularly among preschool children, although nutrition information is available on dietary intake at a particular point of time in some groups.

Changing food habits may affect disease. With the rapidly changing socio-political situation in South Africa diet too must have changed and one cannot rely on previous nutritional information. New reliable information is needed to help plan future health needs of all South Africans.

Dietary intake in association with dental health has been studied by numerous investigators. Regarding energy and specific nutrients, studies have thus far shown no relationship of energy to dental caries incidence; carbohydrate, particularly sugars, have shown both positive and negative relationships to caries incidence and indirectly dietary fats may be associated with low caries because fat and sugar intake are inversely proportional to each other. The role of trace elements has varied from caries promoting to cariostatic. It is clear though that because of the complex nature of the caries process, carbohydrate intake, together with other macro- and micronutrients, does not fully explain the development of this disease. This could be influenced by the fact that most of the studies conducted on diet and dental health have been cross-sectional. The Vipeholm study in Sweden, the Hopewood House study in Australia and more recently the Michigan study in the United States are the

only longitudinal studies that have examined the association between diet and dental caries incidence and both the Vipeholm and Hopewood House studied only selected groups in institutions. Until now no true longitudinal study had been conducted among South African preschool children regarding the association between diet and the development of dental caries. The Birth-to-Ten study is the first such longitudinal study that selected a random sample representative of the population groups in the country and has provided unique information on the longitudinal dietary intake together with the dental health at 1- and 5-years. In addition no South African study has looked at the impact of past diet on the present dental health of the same South African children and the Birth-to-Ten study provided this opportunity.

The overall objective of the present investigation was to study relationships between dietary intake, macronutrient and micronutrient intake and dental health among 5-year-old urban black South African children in a longitudinal cohort, with the following specific objectives:

1. To compare the energy, macronutrient and micronutrient intake of 5-year-old urban black South African children in 1984 and 1995. This is to determine if the dietary intake of 5-year-old urban black South African children has changed over the past decade.

2. To compare the energy, macronutrient and micronutrient intake of 5-year-old urban black South African children who had dietary information in 1991 **and** in 1995 to those who had dietary information for only 1991 or only 1995. This will determine if there was a difference between those individuals who were in the nutrition cohort and those who were not.

3. To compare the energy, macronutrient and micronutrient intake of 5-year-old urban black South African children who had dietary information for 1991 and 1995 as well as dental information for 1995 to those who had only dietary information for 1991 and 1995. This will determine if those individuals who had dietary information for 1991 and 1995 as well as dental information for 1995 differed from those who had only dietary information for the two interceptions.

4. To study the relationship between energy, macronutrient and micronutrient intake and dental caries among 5-year-old urban black South African children, in particular, to determine if any dietary factors could be risk markers for caries in the future.

5. To study the impact of past dietary intake at 1-year on the incidence of dental caries in the same individuals at 5-years among urban black South African children.

6. To determine, together with some dietary variables, the additional influence of some confounding variables (eg. social class, educational level) on the presence of dental caries among 5-year-old urban black South African children.

Two studies were used in this thesis - a 1984 cross-sectional study and two interceptions (1991 and 1995) of the Birth-to-Ten (BTT) study. The 1984 study consisted of 4- and 5-year- old South African children and the 1995 interception of the BTT study comprised children from the same age group (5-years), community (urban black) and from the same

urban area (Johannesburg/Soweto metropolis) as the 1984 study. In addition, the 1995 interception happened to be 10 years after the 1984 study which provided a unique, and ideal, opportunity to assess a decade of dietary change among the same age group, community and from the same area in South Africa. The field work for the 1984 study was done by Dr. B. Richardson and team members of the Dental Research Institute, University of the Witwatersrand, Johannesburg using a dietary history method. For the Birth-to-Ten (BTT) study I, together with trained assistants, did the field work and coding and analysis for both the 1984 and Birth-to-Ten (BTT) studies from food frequency questionnaires.

The sample size design of each community for the Birth-to-Ten study was based on representative proportional samples of the total South African population. With the black population predominating in South Africa there was a large difference in numbers between the communities for this study. This was in contrast to the 1984 study sample design that used equal sized subgroups of approximately 700 subjects for each community. This resulted in only usable subject numbers from the black community. The other communities are thus not included in this study.

To compare change in dietary intake over time, in the same community, area (Johannesburg/Soweto in Gauteng) and age group, the dietary intake of all the 1995 5-year-old urban black children from the Birth-to-Ten study (n=1096) were compared with 5-year-old urban black children studied in 1984 (n=461) in the same area, known then as the Transvaal.

The stored coded dietary and dental data for all the 5-year-old urban black South African children from the longitudinal Birth-to-Ten cohort study (n=1096) was used in this study. From the merged master dietary and dental files the specific data sets of urban black children could be extracted for analysis, those having both nutrition and dental information for 1995 forming the main data set (n=300).

To study the impact of past dietary intake at 1-year with the dental health at 5-years in the same individuals, all the 5-year old urban black children with dietary and dental information at 5-years and dietary data at 1-year (1991 BTT interception) was used (n=300).

The data was analysed in a SUN SPARCcenter 2000 computer on a university network using SAS which involved several statistical tersts:

1. Descriptive tests (mean, standard deviation, 95% confidence intervals)
2. Kruskal-Wallis test to test the diet credibility of the study.
3. Mantel-Haenszel Chi-squared test for quartiles and thirds of nutrients between the dependent variable (3 classifications of dmfs scores) and the independent variables (energy, macro and micronutrients).
4. Linear logistic (Proc Catmod) with three dmfs classifications as the dependent variables and energy, macro- and micronutrients, social class and parents education level as independent variables.
5. General linear models (proc GLM) and logistic regression on transformed dmfs scores, log(dmfs +0.275) for the whole group and log(dmfs+0.3) for the longitudinal group. Again

dental caries was the dependent variable and energy, macro- and micronutrients, social class and parents education level were the independent variables.

The critical level for statistical significance was set at $P<0.05$.

Dietary intake of energy and most macro- and micronutrients increased from 1984 to 1995 among 5-year-old urban black South African children living in the Johannesburg/Soweto metropolis, with the fat intake almost doubling over this time. Dietary intake in 1984 was typical of the prudent diet, high in carbohydrate and low in fat, whereas by 1995 a typical westernised diet was being consumed.

The credibility testing for the study showed that the study groups were representative samples of urban black South African children at 5-years within the Birth-to-Ten study.

Among the macronutrients fat, cholesterol, fibre and added sugar were associated with caries prevalence in the whole group. Energy intake was associated with caries prevalence among the whole and longitudinal groups. When social class and education level were included in the analysis only added sugar was associated with caries prevalence in the whole group of children.

For the micronutrients calcium, vitamins B12, A, B6 and biotin were associated with caries prevalence among the whole group with riboflavin, vitamin E and magnesium being associated for both the whole and longitudinal groups. When social class and education

level were included in the analysis only vitamin B12 was associated for the longitudinal group and vitamin B6 and thiamin for the whole group.

Energy, protein, fat, cholesterol, total available carbohydrate and added sugar were associated with caries incidence for the whole group only. When the children with caries only were analysed these nutrients, with the exception of cholesterol, were associated with caries incidence among the longitudinal group only, with total available carbohydrate being associated for both the whole and longitudinal groups. Ascorbic acid was the only micronutrient that was associated for the longitudinal group with caries.

When social class and education level were included in the analysis energy, protein, fat and of total available carbohydrate were still associated with caries incidence among the whole group of children only, with no macro- or micronutrient being associated for the group with caries only for either the whole or longitudinal groups.

Intake of macronutrients at 1-year was not associated with caries incidence at 5-years among the same children. Among the micronutrients, however, potassium and vitamin B6 were associated.

The association of the nutrients with both caries prevalence and incidence were weak and isolated and therefore not clinically relevant, being mathematical. Nutrient intake, as opposed to the actual food items, is clearly not a risk marker for dental caries incidence among 5-year-old urban black South African children.

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CHAPTER 1.

INTRODUCTION

1.1 Nutrition

It has long been recognised that nutrition is the key to optimal growth and development for children. The first priority of any dietary guidance for healthy children is to emphasise the intake of adequate nutrients for growth and development. A second priority is to focus on the role of diet in disease prevention, dental caries for instance (1)

1.1.1 Definition of nutrition

Nutrition means different things to different people (2). The Concise Oxford dictionary (3) defines the word as: 'the food, nourishment; the study of nutrients and nutrition'. Navia (4) defined nutrition as a multifactorial applied science with a meaning that is difficult to confine within the restrictions of a brief definition. Nutrition is a complex science that involves not only foods and diets but also makes use of principles from biochemistry, genetics, immunology, physiology and molecular biology to deal with the process of incorporating into the body essential compounds from the trophic environment that cannot be synthesised by human tissues. If the understanding is extended beyond tissues and organs, nutrition also includes concepts from behavioural science, sociology, economics, agriculture, and marketing. To make the definition of nutrition still more complex, a major change in the way we think about nutrition and diets has taken place in the past (4).

In the 1940s and 1950s the major emphasis in nutrition was on proteins, amino acids, vitamins and minerals - particularly the search for new essential trace elements to counteract nutritional deficiencies. This period was considered by many as the "Golden Era of Nutrition". Twenty years later scientists left the pursuit of traditional investigations to join the new and exciting field of molecular biology. In the 1970s new scientific evidence gave support to the concept that nutrients were not only essential to growth, development and maintenance of tissues, but were also linked to the expression of genetic information, the effectiveness of the immune system, the prevention of cell damage, and in general, to increased resistance to many chronic diseases and even some infectious diseases. This link to health maintenance and disease prevention resulted in a renewed interest and excitement in nutrition that was expanded beyond the domain of classical nutritional deficiencies. The realisation came about that a diet and its nutritional consequences could have a profound influence on the control and prevention of many chronic conditions such as osteoporosis, cardiovascular disease, hypertension, cancer; it might also play a role in oral diseases, such as dental caries, periodontal disease, salivary gland dysfunction and soft tissue lesions (4). Recent evidence has also linked specific nutrients, such as vitamin A and carotene to the prevention of intestinal and respiratory infections (5).

Navia (4) summed up the newer approach to nutrition in a series of questions dealing with oral health: How well do we in dental research understand these changes and the new health perspectives of nutrition in relation to dental health? How much research effort goes into the definition of oral health outcomes derived from appropriate food choices and nutrient intakes? Do we understand how nutrients contribute to the enhancement of the resistance of

oral tissue to disease, such as dental caries, and the impact that past and present nutrient intake has on the development of this disease? He believed that the answer to these questions is either no or a feeble maybe.

There is a general agreement that many of the chronic diseases of lifestyle such as obesity, diabetes, atherosclerosis as well as dental caries begin in infancy. There is also evidence that the foods eaten during childhood have long lasting and even permanent effects on health in later years. As a result notions about childhood nutrition have expanded from eating well for today's healthy growth and development, to also eating well for tomorrow's disease prevention (6).

1.2 Basic nutritional requirements for healthy development of children

The nature of the change in direction of dietary guidance is best put into perspective by examining the seven guidelines in Harper's reference(7). They are, in reality, a dual set of guidelines. The first two "eat a variety of foods " and "maintain healthy body weight" are essentially guidance for variety and moderation that offer advice on how to select a healthy, nutritionally adequate diet using the food group system. The second guideline is devoted to diseases associated with obesity and to weight reduction. Only after this is there a statement -"children need calories to grow and develop normally ....." . The text accompanying the third guideline "choose a diet low in fat, saturated fat and cholesterol" is almost exclusively devoted to a discussion on cholesterol. It also states that children 2-years and older should be encouraged to choose a diet that is lower in fat and saturated fat. Nothing in this section indicates that everyone needs some fat in their diets. The discussion accompanying the

fourth guideline "choose a diet with plenty of vegetables, fruit and grain products" focuses almost exclusively on fibre and intestinal ailments. "Use sugars only in moderation" deals with tooth decay. Emphasis on the text for guideline six "Use salt and sodium only in moderation" is entirely on elevated blood pressure. Thus five of the seven guidelines focus mainly on diseases associated with aging and imply that diet can be used as a prescription for avoiding them. These guidelines are directed towards overweight, middle aged adults, not children. The special needs of children receive little attention except for advice on how to select a low fat diet. It is children that are the highest risk group for developing the most prevalent disease, dental caries, and no guidelines are directed towards a diet for children that will prevent this disease, besides the advice to consume sugars in moderation.

In the late 1980s sufficient evidence existed for a relationship between dietary factors and chronic disease risk in children to prompt more than ten scientific organisations to issue dietary recommendations and guidelines for children older than 2-years (8). These dietary recommendations and guidelines for children should be viewed both quantitatively (recommendations) and qualitatively (guidelines) (9).

The quantitative recommendations are ultimately to reduce total fat and saturated fat intakes. However, the precise percentage of fat intake to support normal growth while still reducing artherosclerosis risk is not known and many parents tend to overinterpret the need to restrict fat intake. Therefore the American Academy of Pediatrics Committee on Nutrition (10) recommends that children older than 2-years gradually adopt a diet that by the age of 5-years reflects the following pattern of nutrient intake: saturated fatty acids

should be less than 10% of the total energy intake; total fat over several days should be no more than 30% of total energy and dietary cholesterol should be less than 300mg/day. The appropriateness and safety of applying dietary recommendations for fat to children is still debated (11-13). Studies have clearly demonstrated the positive effect of modifying the eating behaviour of children on their serum lipid profiles, while maintaining adequate intakes of energy, essential fatty acids, vitamins and minerals (14). Other studies have shown that the vitamin and mineral content of the diet can potentially be improved when fat is reduced in the diet (15,16). The body of evidence from research now indicates that children can safely consume a diet that conforms to the US Dietary Guidelines, as long as energy intake is adequate and there is variety and moderation in the diet (9).

Ideal fibre intake has not been defined. A recent recommendation for children is to increase dietary fibre to an amount equal to or greater than their age plus 5g/day to achieve intakes of 25-35g/day after the age of 20-years (17).

Recommendations have also been made that children should increase their fruit and vegetable consumption to five or more servings per day (18). Qualitative guidelines are put forth in the Dietary Guidelines for Americans (19) and the Food Guide Pyramid (20) is an excellent tool for educating consumers on how to achieve the dietary recommendations.

It is very difficult to meet childrens' calcium needs without a source of milk in the diet thus, including three servings a day of milk or dairy product is recommended (18).

In general, diets of healthy children that provide adequate energy and nutrients for normal growth should include a variety of foods from each of the major food groups as illustrated by the Food Guide Pyramid (Fig.1.1). Food choices in a total diet should not be restricted because of their caloric, fat or sugar content of any one food. Rather, children should be encouraged to eat a variety of foods in moderate amounts. The key message of variety, moderation and balance in food choice should be promoted to healthy children. (21). The inclusion of qualitative (guidelines) and quantitative (recommendations) advice on maintaining good oral health of children, however, still needs to be addressed, beyond the scope of sugars in these guidelines. In addition, in the absence of guidelines specifically for South African children these US Guidelines have to be applied and may not be appropriate for South African communities.

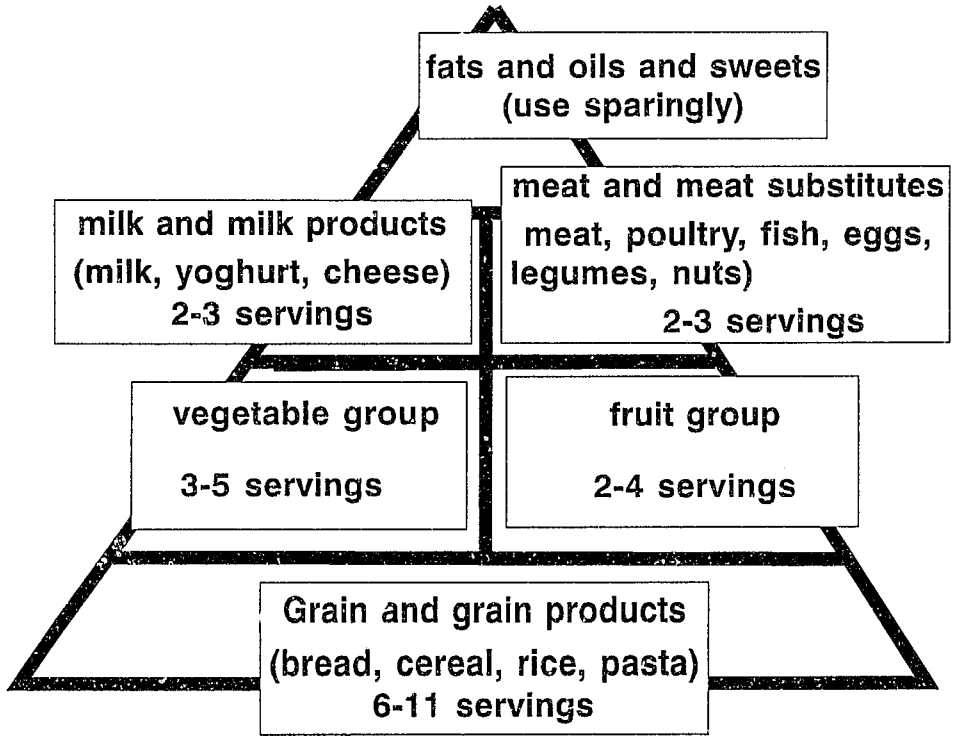


Fig.1.1 The Food Guide Pyramid (1992) (20)

1.3 Epidemiological studies on nutrition and dental caries

The association between nutrition and dental health has been studied by numerous investigators around the world (22-25), the classic study being the Island of Lewis Medical Research Council study (25), but dental data have been published from only 9 of the 18 countries in subequatorial Africa. Just five of these report nutritional research connected to dental caries, dealing almost exclusively with sucrose intake or fluoride ingestion (2). Most of the published data come from studies in North America and Europe, thus providing a view biased towards developed countries with a disease pattern which differs from that in developing countries where malnutrition is rampant among infants and children. In these individuals nutrition and diet constitute an important part of the disease process (26).

If we were to examine the epidemiological caries studies from different parts of the world, it might be concluded that well nourished communities have increased caries rates. This paradoxical situation is believed to be because the posteruptive cariogenic challenge is so strong in the refined diets of industrialised countries that it overpowers the inherent resistance of well formed teeth and body defence mechanisms. In undernourished communities poorly formed teeth may remain sound if the dietary cariogenic challenge is reduced (27).

1.3.1 Caries in the Americas

There is evidence that caries rates are becoming lower in most countries in the Americas. National surveys conducted during the past three decades have demonstrated a decline in the overall mean levels of clinically detectable dental caries in US children (27,28). There is also evidence that the nutritional status of children in most countries in the Americas is improving, but direct evidence that the accompanying decrease in caries rates is related to the increase in nutritional status is lacking (27). However, for those who have lesions the problem is still very real. Improvements in overall nutrition may help reduce the susceptibility to caries (27).

A paper by White *et al* (29) provides an overview of the caries status of people in the US. It was a compilation of data from seven national surveys over a 27 year period. This was not an exhaustive statistical analysis, but a general overview of trends. In children 6-11 years of age the caries rates dropped by almost one half (1.4-0.8 DMFT) and the number of caries free children rose steadily from 44.8% to 71.8% during the review period..

The most extensive research to date in the Americas on nutrition and dental caries has been performed by Alvarez and colleagues in Peru, South America. In a series of three studies they compared the caries rates of children having different nutritional backgrounds. In the first study (30) the investigators compared the nutritional status of 3-9-year-old children to their caries rates. Chronically malnourished children had delayed exfoliation of their primary teeth and delayed initiation of caries. Once started, however, dental caries progressed at the same rate as in children with adequate nutrition. The second study (31) expanded on the

first to include more children over a wider age range, 1-13 years. Because of the younger children studied they were able to confirm that malnutrition did delay tooth eruption and exfoliation, which could increase the potential for developing caries in the primary dentition. The third study (32) was a similar expansion of previous work. In this prospective study children were selected at a very early age, 6-11 months, based on their growth characteristics indicating a single episode of malnutrition. By age four the stunted and wasted group of children had significantly more caries. Their results indicated that a single episode of malnutrition, whether chronic or acute, at a very young age had an effect on tooth eruption and caries rates. This series of studies is by far the best evidence that nutrtion may play a role in caries susceptibility of deciduous teeth. Other studies in the Americas have also supported this (33-36). Evaluation of the evidence from community field trials have also shown that malnutrition or reduced protein-energy intake could lead to the development of enamel hypoplasia (33).

Data from other countries regarding the caries status of communities is limited compared with that which is available in the US (27). Cooney *et al* (37) who compared the caries rates of 6-year-olds in two non fluoridated areas in Manitoba, Canada found a similar rate of caries to 6-year-olds in the US. Another Canadian study by Harrison and Davis (38) compared the caries rates of 5, 7, 9, 11, 13 and 15-year-olds in 1980, 1984 and 1988. They reported that the caries rates had dropped significantly over this time period, but were approximately 2.5 times higher than the US caries rates at the same time in the same age groups.

1.3.2 Caries in European countries

There has been very little research within Europe on the relationship between nutrition and dental caries. With few exceptions, such as the role of trace elements, there has been no evidence that nutrition in children living within Europe affects dental caries, but certain trace elements, such as Molybdenum and Strontium, have been shown to have a negative association with dental caries in epidemiological studies (39). In addition most of the studies on the prevalence and incidence of caries have been carried out on school children and data on preschool children are comparably few (40).

1.3.3 Caries in developing countries, Africa

The fairly high caries prevalence but low dmfs scores seen in Khan's study of South African black preschool children (41) appear to be similar to trends reported elsewhere in Africa (42-45), but in contrast to these other African studies caries rates among the South African children decreased as family education increased, a typical western pattern (41). However nutrient intake was not included in these studies. Other South African studies on dental caries and nutrition have included sugar (sucrose) intake (46-55), selected food types such as sweets and snacks (48,56,57) as well as breast and bottle feeding (58-61). One study (62) conducted on 11-year-old children in Namibia and KwaZulu, Natal, included only energy intake in relation to caries incidence, but up until now diet and nutrient intake as a whole in relation to this disease among South African preschool children has not been investigated.

The distribution of caries in a population is not homogenous, but tends to accumulate in minority groups who are also at higher health risk and undernourished. Decrease in caries indices requires acculturation and education (26).

Many epidemiological studies have thus confirmed a relationship between nutrition and dental caries, the importance of the nutritional status of an individual during the early years of development as well as the foods consumed and dietary habits and the maintenance of oral tissue during a lifetime.

During the last 30 years there has been major progress in the understanding of this relationship, yet the importance and true nature is still misunderstood and frequently ignored. The dietary habits practiced, the foods eaten and the nutrients provided by them influence growth, development and maintenance of tissue and organs, particularly the oral tissue that comes into contact with foods directly. In recent years the impact of nutrition on general health has been increasingly evident (4). Nutrients provided by specific diets have been shown to influence the control and prevention of several chronic conditions. Furthermore research findings (4) have provided evidence that foods play an important role in many oral diseases and pathoses such as dental caries, periodontal disease and salivary gland dysfunction, (26). Nutrition is also an important factor in the development and continued integrity of all tissues and organs, including the soft and hard tissue of the mouth (27). Yet, regardless of the evidence presented supporting the existence of the role of diet, foods and nutrients in dental caries, the awareness and understanding of the oral health impact of this relationship has been limited (27).

The nutritional effect on teeth, in contrast to diet or food intake, and subsequent caries development is one of the least established relationships. Any effect attributed to nutrition has its maximum effect prior to tooth eruption, and because of the extended time between tooth formation and the onset of decay, the relationship between nutritional influence and caries formation is very difficult to identify (27). The teeth once exposed to the oral cavity and fully matured are less affected by nutrition than by diet (27). Although the nutrient effect on teeth is one of the least established relationships, it is still a determinant of the most prevalent infectious disease in paediatrics: dental caries (63).

1.4 Conclusion to literature review

Studies of various populations eating reduced amounts of sugar during periods of war (64), studies of populations who eat low levels of sugar (65), and studies of populations given high sucrose intakes (66) and a multitude of other studies have indicated that, on a population basis, increased sugar intake is associated with a greater risk of dental caries. It can therefore be concluded from epidemiological evidence that sugar in the diet is a causal factor in the development of dental caries. However, several recent comprehensive reviews examining more than 200 papers which evaluate health education or promotion, have failed to find a single robustly designed study which has shown a reduction in caries consequent to a sugar reduction programme regardless of whether the intervention took a community or individualistic approach. It is thus no longer enough to faithfully believe that we are preventing disease, or promoting health by suggesting that people reduce their sugar intake, if there is no evidence to support that this is an effective activity (67). It is obvious that the role of sugar in the etiology of dental caries must be revised (68) and the diet as a whole

(energy, macro- and micronutrients) in relation to oral health must be considered, something that up until now has not been fully investigated. While sugar remains a risk factor, caries incidence is affected by many other factors such as overall nutrition, the number of meals and snacks per day, education and motivation, fluoride, socio-economic group, ethnicity, oral hygiene status, use of preventive methods and sweeteners other than sucrose (68), and thus sugar intake alone or together with other macro- and micronutrients, does not

fully explain the development of dental caries. This could be influenced by the fact that most of the studies conducted on diet and dental health have been cross-sectional. The Vipeholm (66) and Hopewood House (69) studies, and more recently the Michigan study (70) are the only longitudinal studies that have examined the association between diet and dental caries incidence in the permanent dentition, two of which studied only selected groups in institutions (66,69), one group consisting of mentally retarded individuals (66). Longitudinal studies have concentrated mainly on bacteriological rather than dietary variables (71). No true longitudinal studies have previously been conducted on South African preschool children regarding the association between diet and the development of dental caries. South Africa now has a longitudinal study, the Birth-to-Ten (BTT) study which selected a random sample of subjects representative of the population groups in the country. This study will provide unique information, being the only South African study to describe the longitudinal detailed dietary intake of the representative South African populations, as well as their dental health at 1 and 5 years. In addition no studies have looked at the impact of past diet on the present dental health of the same South African children and this Birth-to-Ten (BTT) study provides this opportunity. In fact, Roeters (72) states that in the dental literature the

number of longitudinal studies, throughout the world, focusing on dental caries and its determinants in preschool children is limited in comparison to older age groups and even then these studies too have mainly been restricted to bacteriological variables.

1.5 Objectives

The overall objective of this investigation was to study relationships between dietary intake, macronutrient and micronutrient intake and dental health among 5-year-old urban black South African children in a longitudinal cohort, with the following specific objectives:

1. To compare the energy, macronutrient and micronutrient intake of 5-year-old urban black South African children in 1984 and 1995. This is to determine if the dietary intake of 5-year-old urban black South African children has changed over the past decade.

2. To compare the energy, macronutrient and micronutrient intake of 5-year-old urban black South African children who had dietary information in 1991 **and** in 1995 to those who had dietary information for only 1991 or only 1995. This will determine if there was a difference between those individuals who were in the nutrition cohort and those who were not.

3. To compare the energy, macronutrient and micronutrient intake of 5-year-old urban black South African children who had dietary information for 1991 **and** 1995 **as well as** dental information for 1995 to those who had only dietary information for 1991 **and** 1995. This will determine if those individuals who had dietary information for 1991 and 1995 as well as

dental information for 1995 differed from those who had only dietary information for the two interceptions.

4. To study the relationship between energy, macronutrient and micronutrient intake and dental caries among 5-year-old urban black South African children, in particular, to determine if any dietary factors could be risk markers for caries in the future.

5. To study the impact of past dietary intake at 1-year on the incidence of dental caries in the same individuals at 5-years among urban black South African children.

6. To determine, together with some dietary variables, the additional influence of some confounding variables (eg. social class, educational level) on the presence of dental caries among 5-year-old urban black South African children.

CHAPTER 2

MATERIALS AND METHODS

Two studies were used in this thesis - a 1984 cross-sectional study and two interceptions (1991 and 1995) of the Birth-to-Ten (BTT) study. The 1984 study consisted of 4- and 5-year-old South African children and the 1995 interception of the BTT study comprised children from the same age group (5-years), community (urban black) and from the same urban area (Johannesburg/Soweto metropolis) as the 1984 study. In addition, the 1995 interception happened to be 10 years after the 1984 study which provided a unique, and ideal, opportunity to assess a decade of dietary change among the same age group, community and from the same area in South Africa. The field work for the 1984 study was done by Dr. B. Richardson and team members of the Dental Research Institute, University of the Witwatersrand, Johannesburg. For the Birth-to-Ten (BTT) study I, together with trained assistants, did the field work and coding and analysis for both the 1984 and Birth-to-Ten (BTT) studies.

Prior to the commencement of the 1984 and Birth-to-Ten (BTT) studies ethical approval was obtained from the University of the Witwatersrand Committee for Research on Human Subjects.

2.1 1984 study

2.1.1 Population

During January and February 1984 an extensive field study was undertaken on 2 821 4- and 5-year-old rural black, urban black, Indian and white children living in, what was then known as, the Transvaal province of South Africa. This included part of Bophuthatswana for the rural community and Soweto, Lenasia and Johannesburg for the urban communities. The aim of the study was to examine caries susceptibility in different ethnic groups with due consideration to the role of confounding variables (73)

In this study a good representative sample of equal size of each subgroup was used, approximately 700 subjects from each. This age group was selected as they are widely influenced by family and cultural eating patterns, not having a great deal of opportunity to select items for themselves. They are able to communicate with the interviewer, and children tend to give more honest dietary records than adults (74,75). Adults tend to answer what they think is expected of them, not what has actually been consumed.

In each geographic area health centres and clinics were selected so that both high and low income areas were represented. Within each area children were randomly selected from local birth records as follows:

1. Rural blacks - Gelukspan district of Bophuthatswana, with a total of 699 from the Mareetsane-152, Madibogo-165, Setlagole-142, Kraaipan-69, and Gannalaagte-171 communities.
2. Urban blacks - Soweto with a total of 785 from Shanti Clinic-174, Mofolo Clinic-134,

Senaoane Clinic-96, Jabavu Clinic-67, Orlando East-90, Zondi East-143, and Pimville Clinic-81.

3. Urban Indians - Lenasia with a total of 607.

4. Urban whites - Johannesburg with a total of 730 from Claremont Clinic-52, Triomf Clinic-42, Southern areas Health Clinic-57, Northern areas Health Clinic-65, Bellavista-22, Orchards-36, Western areas-122, Yeoville-42, Eastern areas-56, King Davids-81, Coronation Nursery School-32, Mary Help of Christians Nursery School-74, and Lilliputs Nursery School-49.

2.1.2 Dietary methodology

The dietary survey was organised and supervised in the field by Dr. BD. Richardson of the Epidemiology section of the Medical Research Council's National Research Institute for Nutritional Diseases. For completeness, details of the techniques that they used will be described in sections 2.1.2.1 to 2.1.2.4.

2.1.2.1 Interviewers

Interviewers were trained by Dr. BD. Richardson and Mrs. R. Sinwel of the Medical Research Council's Research Institute for Nutritional Diseases and involved a detailed explanation of the questionnaire and how to cross question the subjects to determine the accuracy of the information given. The interviewers were staff members of the Research Institute for Nutritional Diseases, of the Medical Research Council/University of the Witwatersrand Dental Research Institute as well as nursing staff and teachers of the various schools and clinics. Most of the interviewers were familiar with the relevant languages

which limited the communication barrier. The interviews were conducted at the school/clinic and parents or guardians were asked to be present on the relevant day to assist in providing the required information. All those present on the day of the examination were interviewed. In the majority of cases the information was obtained from the child's mother, otherwise from a guardian or care-giver who could be the grandmother, relative or friend.

2.1.2.2 Dietary history questionnaire

The dietary history questionnaire method was used in the study, a method that Vorster *et al.* (76) had proved to be reliable among South African ethnic groups. The questionnaire used is in Appendix A. It was divided into 20 food groups each of which had further subdivisions into various specific food examples. This helped to assist in the recalling of foods eaten (77). This questionnaire was rapid since an interviewer was only required to tick a food item and write in the quantity consumed. This was a very important consideration with the large number of subjects involved. The information recorded was the amount consumed in grammes, teaspoons, tablespoons, portions, cups or slices; when the food was eaten, either during or between meals and the frequency that the food was consumed, ie. daily, weekly, monthly, seldom or never. In additio , to the dietary information the questionnaire required the subject's name, sex, code number (for the survey), school, date of birth and date of survey as well as the educational level of both parents and oral hygiene procedures used.

2.1.2.3 The interview

Each interview took approximately 20-25 minutes. Where there was doubt as to the quantity of food items consumed visual hand sizes or comparisons were used to estimate

portion size. If the subject appeared to be vague about when a food item was consumed, specific times were mentioned by the interviewer. Some forms were incomplete or lost, children were absent on the examination day, or too young, reducing the final numbers of records used to: rural blacks - 690, urban blacks - 782, urban Indians - 598 and urban whites - 730, to a total of 2800.

2.1.2.4 Dietary calculations

In the laboratory, the household measures were converted to grammes using the standard amounts set out by the Medical Research Council and for each food item the amount consumed per week in grammes was calculated. These results were written onto computer coding sheets (Appendix B) using the National Research Institute of Nutritional Diseases Food Composition Tables (78). I, together with three staff members of the Dental Research Institute coded the data.

Each computer data sheet consisted of 8 columns and 10 rows. The first 6 blocks of the first card indicated the study year and computer code number (ID code) of the individual and the last 2 blocks the card number, starting with 05 for dietary intake. In the second row of the first card the first 4 blocks indicated the individual's decimal age, followed by the sex code (male=1, female=2), ethnic group code (rural black=8, urban black=7, urban Indian=3, urban white=1), eating and swallowing pattern (0 for this study as it was not included). The other 8 rows of the first card consisted of food items, the first 4 blocks of each row being the food code, followed by the amount consumed in grammes per week in the next 4 blocks. The top row of each subsequent card for the same individual had the same year and

the same ID code number as card 1, with the last 2 blocks of the first row being the consecutive card number -06. The next 9 rows comprised the food item codes and amounts as in card 1. This continued for each consecutive card until all the food items mentioned in the dietary history of the individual had been entered onto the coding sheet.

2.1.3 Computer methodology

The completed coded data sheets were sent to a data capturing service (Omnidata, Rissik Street, Johannesburg) to be put onto magnetic computer tape, which was then mounted and stored on an online disk in the University of the Witwatersrand IBM 3083-J24 mainframe computer. The 1984 study was undertaken on this stored nutritional information.

The Medical Research Council's (MRC) Modified Executive Programme (modexec), using Fortran, was applied to the raw data for each ethnic group to modify this for analysis for the other MRC dietary analysis programmes. This modification involved systematic rearrangement of the raw data, separating the reference number for each individual from the card number, decimal age, sex, ethnic group and from the food item code and amount. Modified files were then created for each ethnic group. Although the raw data was collected by Dr. B. Richardson and field workers, I modified and analysised it .

The MRC Nutrition Executive Programme (nutexec) was run on the modified data of each ethnic group to analyse the nutrient intake of each individual. The programme read the updated 1986 nutrient table comprising 31 nutrients. Similar to the modified files, nutrient files were created for each ethnic group.

The Statistical Analysis System version 5 (SAS) (79) was used for statistical analysis. A Proc Means procedure was run to calculate the daily mean nutrient intakes and standard deviations per food item for each group. Ninety-five percent confidence intervals and median values were also determined.

2.2 The Birth-to-Ten (BTT) Study

2.2.1 Main objective of Birth-to-Ten study

The BTT study commenced in 1990. It is a longitudinal prospective observation study which plans to follow the biological, environmental, social, economic and psychosocial factors associated with the survival and health of some 2000 urban South African children from the black, "coloured" (African-European-Malay), Indian and white communities over a 10 year period, living in the Johannesburg/Soweto area in the Gauteng province, previously the Transvaal province of South Africa.

Nutrition and dental interceptions of the study took place in 1991, 1992 and 1995 when the children were 1, 2 and 5 years of age, respectively. For the 1992 interception Soweto was not included in the survey due to a lack of field workers and thus the number of subjects for this year was very low so was not included in the current study.

2.2.2 Population

This study (BTT) comprised all births during a 7-week period from 23rd April to 8th June 1990. The source of the study population (sample) was the official birth notifications, governed by a local ordinance, and completed by medical, nursing and midwifery staff at the

time of every birth in the area. Five thousand four hundred and sixty singleton births occurred during this time to women who gave a permanent address in pre-designated areas of the Johannesburg/Soweto metropolis irrespective of where the delivery took place. Enrolment into BTT took place during the first 15 months of the study and covered antenatal, delivery, 6 month and 1 year periods. By the end of this time 74% of all births (4 029 cases) had been enrolled into the study, but there were marked variations in levels of enrolment by population group, residential area and place of delivery. Seventy eight percent of all births in the black community within the prescribed time frame were enrolled, 86.5% from the "coloured" community, 69.5% from the Indian and 38% from the white communities(80).

The sample size design of each community was based on a representative proportional sample of the total South African population. The black community predominates in South Africa, making up 76% of the total population according to the 1994 Census (81). The percentages of the total population for the other groups were; "coloureds" - 8%, Indians - 3% and whites - 13% (81). Within the black community 2-5-year-olds make up 12% of the total. Hence there was a large difference in numbers between the communities for this study. This was in contrast to the 1984 study sample design that comprised equal sized subgroups, approximately 700 subjects from each population group.

2.2.3 Dietary methodology

Choice of nutrition assessment method is difficult and after examination of the literature since 1984 (82-88) a semi-quantitative food frequency questionnaire appeared to be the

most appropriate method for large scale studies, such as the BTT, in culturally diverse populations. The method had been validated earlier by Margetts *et al.* (85) and has recently been found to be reproducible, relatively valid and culturally sensitive in assessing the dietary intake of black South Africans in the North West Province (89) This was thus the method of choice for both the 1991 and 1995 nutrition interception of the BTT study. The foods listed in the questionnaire were based on many years of experience in diet assessment among South African children, and was designed to obtain a picture of the childrens' diet as a whole, rather than to categorise or rank selected nutrients. This conformed with the aim of the BTT study which is to assess the overall health of urban South African children.

2.2.4 Birth-To-Ten (BTT) - 1991 interception

2.2.4.1 Dietary methodology

a) Food frequency questionnaire

For the 1991 study the food frequency questionnaire (Appendix C) comprised food items listed in 13 food groups under beverages; cereals and porridges; bread and biscuits; spreads; cakes, puddings, snacks; sugar, sweets and chocolates; protein sources; starches; fruit; vegetables; sauces; oil and soup. Selected food items were listed under each food group. The frequency categories for each food item listed within the groups were: seldom or never, 1/month, 2-3/month/, 1/week, 2-4/week, 5-6/week, 1/day, or 2 or more times/day.

b) Interviewers

The interviewers were retired nursing sisters who were familiar with most of the official languages of South Africa. They were trained by two of the staff members of the Dental

Research Institute at the Chris Hani Baragwanath Hospital two days prior to commencement of the survey. The training sessions involved a detailed explanation of common dietary assessment techniques, explanation and familiarisation with the food frequency questionnaire to be used through practical application of the questionnaire.

c) Interview

Parents or guardians were asked by the trained interviewers to indicate how frequently the listed food items were consumed. The interviewer merely had to place a tick in the appropriate frequency column for each listed food item. This simplified the assessment and reduced the time taken for the interview, which was an important aspect to consider with the large number of subjects. Interviews took place during April-May 1991 at the following clinics in the Johannesburg/Soweto area: Pimville, Mofolo, Zondi, Diepkloof, Meadowlands, Orlando, Chiawelo, Shanty, Zola, Tladi, Jabavu, Senaoane, Westbury, Noordgesig, Kliptown, Eldorado Park, Mayfair, Lenasia, Parkhurst, Berea, Crosby, Jeppe and Rosettenville. Home visits were also conducted in some of these areas. Parents or guardians were notified of the day interviewers would be present at the respective clinics and all participating subjects present on the day of the visit were interviewed.

d) Coding

Two staff members of the Dental Research Institute coded the data onto computer coding sheets (Appendix D) using the 1991 South African Medical Research Council Food Composition Tables and Codes (90). Standard portion sizes were used. The portion sizes were calculated from standard portions used for older individuals in previous surveys

together with the National Research Institute for Nutritional Diseases (NRIND) Food Quantities Manual (91).

2.2.4.2 Dental methodology

a) Dental examination

The same interviewers that conducted the dietary questionnaire were also trained in dental examination by the Director of the Dental Research Institute at the Chris Hani Baragwanath Hospital two days prior to commencement of the survey. As the children had very few erupted teeth dental examination was simple. Some carious teeth mounted in plaster blocks were used as examples. Examination took place at the clinic at the same time as the dietary interview, in good natural light using a mirror and sharp probe. Caries was diagnosed when the probe caught in a suspicious area. The information was recorded onto computer coding forms, based on those of the World health Organisation (WHO) (92). As all examiners were trained in dental assessment most of the children participating in the study could be examined.

b) Dental coding form

The dental coding form (Appendix E) recorded the following information: card 1 (1 written in block 1) comprised 43 blocks of demographic data. Blocks 2-7 indicated the child's ID code (2-3 being the year of the survey and 4-7 being the reference number) which was the same code as that used on the dietary forms and is the standard Dental Research Institute system; blocks 8 and 9 were the child's age in years, recorded as 01 for all the subjects. Block 10 indicated "F" or "M" for the child's gender and block 11 indicated the South

African population group - "B"=black, "C"= "coloured", "I"= Indian and "W"= white. Blocks 12 and 13 indicated area and block 14 was the environment, "1"= rural and "2"= urban. This study comprised only urban environments so "2" was the standard code used. Blocks 15-18 indicated the codes for the father (blocks 15 and 16) and mother's (blocks 17 and 18) occupation and blocks 19-22 father (blocks 19 and 20) and mother's (block 21 and 22) education. Blocks 23 and 24 were left blank and blocks 25-31 was the child's Birth-to-Ten reference number allocated by the Birth-to-Ten offices at the time of enrolment. Blocks 32-37 indicated Streptococcus counts and 38-43 indicated debris score according the simplified Greene and Vermillion Index (92) taken from three teeth in the upper and lower left quadrants (55, 51, 65) and three teeth in the upper and lower right quadrants (75, 71 and 85). At one year of age only the 51 and 71 teeth could be recorded.

On cards 2 to 4 (2, 3 or 4 written in block 1), ID code of the subject was repeated in blocks 2-7. Dental caries was recorded in the upper and lower left quadrants of the mouth as decayed, missing or filled surfaces (dmfs) for the primary dentition on cards 2 and 3. The surfaces were the buccal, mesial, distal, lingual and occlusal, recorded for each tooth.

On card 4 enamel hypoplasia was recorded in blocks 8-27 for each tooth.

2.2.5 Birth-to-Ten (BTT) - 1995 interception

2.2.5.1 Dietary methodology

a) Food frequency questionnaire

The 1995 food frequency questionnaire (Appendix F) differed slightly from that of 1991 for

two reasons. The children were older and during an overseas trip, in 1993, visiting nutrition institutes in Britain and Canada, I gained a great deal of insight into dietary assessment methods and was able to modify the questionnaire based on that used at the Rowett Research Institute in Aberdeen, Scotland. The 1995 questionnaire thus comprised food items listed under 8 food groups, namely; grain and cereal group; breakfast cereals and porridges; other starches; meat and meat substitutes; vegetables and fruit; fats and oils; milk and milk products and a group miscellaneous which included tea, coffee, sugar, sweets, cooldrinks, cakes, biscuits, puddings and snack foods such as crisps and popcorn and spreads such as marmite and bovril. The frequency categories for each food item listed within the groups were 7,6,5,4,3,2 or 1/week, "M" for monthly, "R" for rarely. In addition there were open-ended questions for the subjects to name the types of fruit and vegetables consumed in the past week, whether most of these were consumed cooked or raw, and the preparation method used. Some of the food groups requested the subjects to indicate the amount consumed such as the number of slices of bread, amount of milk and number of teaspoons of sugar. The subjects were also asked to indicate how many meals and in-between snacks the children consumed per day. A separate section on the questionnaire was an abbreviated 24-hour recall in which the parents were asked to indicate how many portions from 7 food groups; namely: milk, meat/fish/chicken/cheese/eggs/nuts/legumes; fruit; vegetables; potatoes; bread/cereal/porridge/rice/ pasta/maize meal/samp/mielierice; oil/butter/margarine/cream/non-dairy creamers/salad dressing; their child had consumed in the preceding 24-hours. The interviewer just had to circle the number of portions that ranged from 1 to 10. They also indicated if these portions were typical of the child's normal consumption on an average day. These additional questions were used as a cross-check with

the food frequency qi estionnaire to minimise over-estimation, typical of the food frequency questionnaire. For example the number of portions of meat or meat substitutes consumed in the preceding 24 hour should have corresponded with the frequency categories circled in the food frequency section.

b) Interviewers

Three interviewers were trained and directed by two members of the Dental Research Institute/University of the Witwatersrand in interviewing techniques of the questionnaire two days before commencement of the 1995 interception. The training again involved a detailed explanation of dietary assessment methods and in particular the questionnaire to be used. They were required to familiarise themselves with the format and foods listed in the questionnaire and carry out practice sessions between themselves and on patients in the Dental Hospital. The interviewers were familiar with most of the official languages of South Africa.

c) Interview

Parents or guardians were asked by four multi-lingual trained interviewers (the three trained assistants and one staff member of the Dental Research Institute), over a 7 month period (from April to October 1995), to indicate how frequently the listed food items were consumed per week. Interviews were conducted at Noordgesig, Bosmont, Riverlea, Berea, Parkhurst, Jeppe and Rosettenville, Crosby, Eldorado Park, Kliptown, Mayfair, Lenasia and Westbury Clinics, but most of the time was spent at the Chris Hani Baragwanath Hospital. Unlike the 1991 interception, parents or guardians were notified of the 1995 follow-up and

appointments were made for them on the specific day and transport was provided when needed, hence the long surveying period for this interception in comparison to 1991. A very experienced assistant from the Dental Research Institute was present each day to check the recording of the other interviewers. I also visited the hospital on occasions to check all the interviewers.

d) Coding

For the 1995 BTT data four trained assistants and one staff member of the Dental Research Institute coded the data during February and March 1996. Three of the assistants had also conducted the interviews in 1995. Standard portion sizes were used, based on a portion size questionnaire completed by 50 randomly selected individuals during the survey and the use of the National Research Institute for Nutritional Diseases (NRIND) Food Quantities Manual (91). Food items were coded onto computer coding forms using the 1991 South African Medical Research Council (MRC) Food Composition Tables and Codes (90).

e) Coding sheets for 1991 and 1995 BTT study

Each computer data sheet (Appendix D) consisted of 10 columns and 10 rows. The first 6 blocks of the first card indicated the year of study (91 or 95) and computer code number (ID code) of the individual, the next 2 blocks were left blank with "0" written into them and the last two blocks the card number starting with 05 for dietary intake. In the second row of the first card the first 4 blocks indicated the individual's decimal age, followed by the sex code (male=1, female=2), ethnic group code (urban black=7, urban "coloured" -5, urban Indian=3, urban white=1), the dietary assessment method used (04 for food frequency

questionnaire) and the last 2 blocks indicated the day of recording. In this case "00" was filled into these blocks as the survey did not involve dietary intake assessment over a number of days as is used in a dietary record. The other 8 rows of the first card consisted of food items, the first 4 blocks of each row being the food code, followed by the amount consumed in grammes in the next 4 blocks and the last 2 blocks indicated the frequency of consumption. For the 1991 interception the following codes were used for the frequencies: 1/month - 01, 2-3/month - 02, 1/week - 03, 2-4/week - 04, 5-6/week - 05, 1/day - 06, 2 or more/day - 07, and for the 1995 interception: 1/week - 01, 2/week - 02, 3/week - 03, 4/week - 04, 5/week - 05, 6/week - 06, 7/week - 07.

The top row of each subsequent card for the same individual had the same year and the same code number as card 1, with the last 2 blocks of the first row being the consecutive card number -06. The next 9 rows comprised food item codes and amounts as in card 1. This continued for each consecutive card until all the food items mentioned in the questionnaire of the individual had been entered onto the coding sheet.

The same individual seen in 1991 and 1995 kept the same 6 digit ID number for both years, only the first 2 digits would differ, for the year of study, ie. 91 or 95. For example, an individual seen in 1991 may have been given an ID code of 914001. If that same individual was seen again in the 1995 interception his/her ID code would be 954001.

2.2.5.2 Dental methodology

a) Dental examination

As mentioned previously the survey period extended over 7 months for this interception. There was not the manpower to have a qualified dentist at the survey sites on each day throughout this period. Two dentists from the University of the Witwatersrand were calibrated beforehand (93) and went on selected days to the survey sites and examined subjects present on that day. This accounted for the lower number of subjects with dental information, than for nutrition, for this interception. Similar to the 1991 interception, examination was in good natural light using mirror and sharp probe and caries was diagnosed when the probe caught in a suspicious area, pit or fissure according to the WHO criteria (92). Exfoliated teeth, or teeth lost due to trauma were regarded as healthy.

Oral hygiene was determined using the oral debris index (DI-S) of Greene and Vermillion (92). A sickle-shaped probe was run over the buccal surfaces of teeth 55, 51, 65, 75 and 71 and 85 and any debris noticed was recorded. If none was found the score was 0, if debris was present on less than one-third of the crown the score was 1, if debris was present on two-thirds the score was 2 and if the entire surface was covered the score assigned was 3. The mean debris score was then calculated in each individual. All the information was recorded onto computer coding forms. Although this was done it did not form part of the current study.

b) Dental coding form - 1995

The 1995 dental coding form (Appendix G) was very similar to the 1991. The format of

card 1 for blocks 2-43 was the same as that for 1991, consisting of demographic data with ID code in blocks 2-7, child's age in years in blocks 8 and 9. In this case "05" was recorded for all the subjects. Child's gender, "F" or "M" was recorded in block 10 and South African population group in block 11. Block 12 and 13 indicated area and block 14 environment, "2" for urban as in 1991. Blocks 15-18 indicated the codes for the father (blocks 15 and 16) and mother's (blocks 17 and 18) occupation and blocks 19-22 father (blocks 19 and 20) and mother's (block 21 and 22) education. Blocks 23 and 24 were left blank and blocks 25-31 was the child's Birth-to-Ten reference number allocated by the Birth-to-Ten offices. Blocks 32-37 indicated Streptococcus counts and 38-43 indicated debris score according the Greene and Vermillion Index. Additional data for 1995 was the mutans streptococci count of the mother's saliva, recorded in blocks 44-49.

The format of cards 2, 3 and 4 was identical to the 1991 form.

2.2.6 Computer methodology

For both 1991 and 1995 BTT interceptions the completed coded sheets (dietary and dental) were sent to a data capturing company (Omnidata, Rissik Street, Johannesburg) to be put onto computer disks. The data were then transferred onto the University of the Witwatersrand Academic Unix Server (Venus) and analysed in a SUNSPARCcenter 2000 This was the upgrade of the university system that had replaced the previous IBM mainframe computer system. The large data sets involved extensive cleaning, which took a considerable amount of time, not only with correcting each individual data set but matching the corresponding subjects for each interception, both for dietary and dental data.

The dietary data sets were verified together with the coded data and a second verification on about 5% of the data was done by a third person, a staff member of the Dental Research Institute.

SAS programmes , written specifically for the research, were applied to the dietary data sets to:

1. Modify the raw data, similar to the modexec programme used for the 1984 data, and calculate the daily amount from the intake frequency and subsequently create new data sets, BTT91.data and BTT95.data. This programme involved multiplying the standard portions consumed in grammes by the frequency (Tables 2.1 and 2.2).

Table 2.1 Frequency categories, codes and calculation conversions for the 1991 interception

Frequency	frequency code	calculation conversion
1/month	01	1/30 = 0.03
2-3/month	02	2.5/30 = 0.08
1/week	03	1/7 = 0.14
2-4/week	04	3/7 = 0.43
5-6/week	05	5.5/7 = 0.79
1/day	06	7/7 = 1
2 or more times/day	07	14/7 = 2

Table 2.2 Frequency categories, codes and calculation conversions for the 1995 interception

frequency	code	calculation conversion
1/week	01	1/7 = 0.14
2/week	02	2/7 = 0.29
3/week	03	3/7 = 0.43
4/week	04	4/7 = 0.57
5/week	05	5/7 = 0.71
6/week	06	6/7 = 0.86
7/week	07	7/7 = 1

2. Apply a SAS programme, developed for this PhD, to the new data sets to calculate the daily nutrient intake for each individual and created SAS nutrient sums data sets. This programme read the 1991 South African Medical Research Council's nutrient table which gives the nutrient values per 100g. Therefore the programme divided the daily amount consumed for each individual by 100 to obtain the nutrient intake.

All further analysis used the nutrient sums data sets.

South African society is characterised by a population structure in which cultural and socio-economic factors probably influence eating patterns and therefore nutrient intakes. It was therefore decided to keep intakes of the main population groups; namely, blacks, "coloureds", Indians and whites, separate even though they are now all South Africans in

the new South Africa. The terms black, "coloured", Indian and white are used for uniformity as these terms have been most commonly used in publications and are still used in the official government census reports (94).

This thesis will only report on children from the urban black community for both the 1984 and Birth-to-Ten (BTT) studies. As mentioned previously the black community makes up 76% of the total population. This fact, together with the more usable subject numbers in the 1995 study interception, made the black community the choice for this study. The number of subjects for the other 1995 groups were too small to be used, particularly true of longitudinal subjects.

2.2.6.1 Comparing change in dietary intake in 1984 and 1995

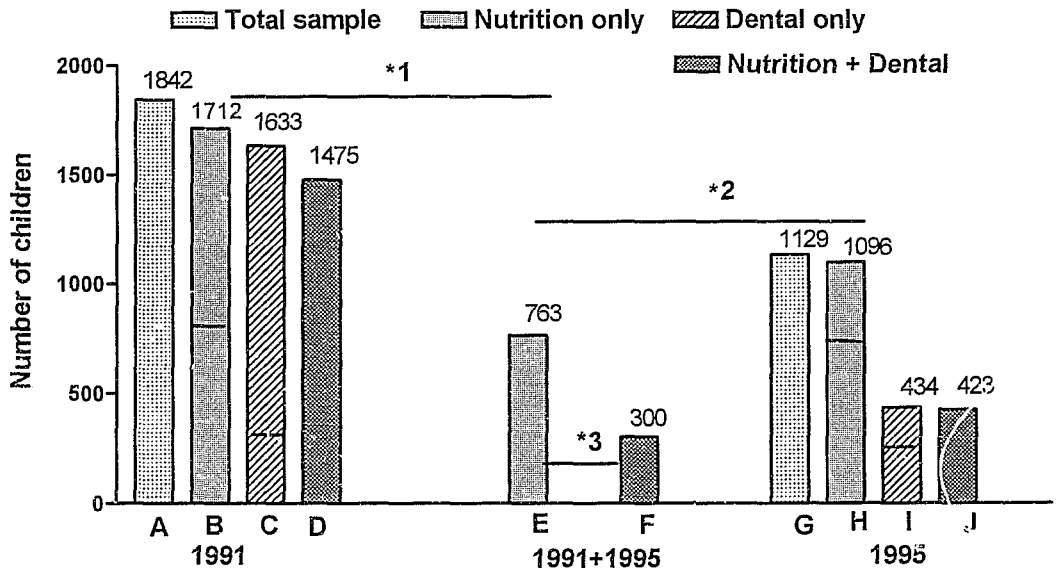
To compare change in dietary intake, in the same community, area (Johannesburg/Soweto in Gauteng) and age group, the dietary intake of all the 1995 5-year-old urban black South African children [n-1096] was compared to 5-year-old urban black children studied in 1984 in the same area [n=461], known then as the Transvaal. Descriptive statistical tests were carried out on the merged 1984 and 1995 nutritional data after the data had been tested for normality. Details of the statistical tests are discussed in chapter 3.

2.2.6.2 Description of Birth-to-Ten (BTT) data sets for 1991 and 1995

Several data sets were used in this thesis and are shown in Figure 2.1. From a total sample of 1842 urban black children that enrolled in the BTT Study in 1991, 1712 had nutrition

information and 1633 had dental information. In 1995 a total of 1129 urban black children were enrolled, 1096 having nutrition information and 434 having dental information. A total of 763 of these children had nutrition information for both 1991 **and** 1995 **with or without** dental information for 1995. As very few 1-year-olds in 1991 had dental caries and not all teeth had erupted only dental data for 1995 was the criteri· · for being in the 763 cohort. Of these 763, 300 were true longitudinal subjects having nutrition information for 1991 **and** 1995 **and** dental data for 1995. Two hundred and fifty nine of the 300 subjects had nutrition as well as dental information for both interceptions. The remaining 41 subjects did not have dental information for 1991. Missing individuals in the data sets did not attend for examination or were lost in the study.

In all cases sample size was defined the number who participated in the study. For the statistical analysis power was set at 0.80, and alpha at 0.05.



* Comparison of nutrition results and dental results in true cohort and in children seen once to test for representativeness:
comparison 1 B to E, 2 E to H and 3 E to F

Note: 763 subjects in 1991+1995 are indicated in columns B and H by horizontal lines within the columns. Similarly, 300 subjects in 1991+1995 are indicated in columns C and I by horizontal lines within the columns. This is to indicate the proportions of the relative samples.

Fig.2.1 Number of urban black 5-year old urban black South African children for nutrition and dental data in the 1991 and 1995 Birth-to-Ten interceptions

The transferred dental data for 1991 and 1995 were merged with the nutrient sums data sets using SAS and one large data set comprising all the nutrition and dental information for 1991 and 1995 was created together with several variables that enabled specific data sets, according to the objectives of the study, to be extracted for further analysis.

2.2.6.3 To study the relationship between energy, macro- and micronutrient intake and dental caries among 5-year-old children

Only the general principles of all the statistical tests carried out are discussed in chapter 2. The specific tests are discussed in detail in chapters 4 and 5.

The data from the BTT 1991 and 1995 interceptions were first tested for normality to test for the dietary credibility of the study. Statistical analysis for prevalence and incidence of dental caries in relation to energy, macro- and micronutrient intake was carried out. Details of the statistical tests are discussed in chapter 4.

2.2.6.4 To study the impact of past dietary intake at 1-year with the dental health of the same children at 5-years

The final stage was to study the impact of past dietary intake at 1-year with the dental health of the same individuals at 5-years. The Mantel-Haenszel x^2 test for trend was carried out on each nutrient in quartiles and thirds and regression analysis on dmfs and transformations of log(dmfs + k) for children in the whole longitudinal group [n=300] as well as for those individuals within this group that had caries only [n=184]. Details of the statistical tests are discussed in chapter 5.

CHAPTER 3.

CHANGE IN ENERGY, MACRO- AND MICRONUTRIENT INTAKE IN 1984 AND 1995

3.1 Introduction

There is a general agreement that food habits change over time (95).Changes in food habits have occurred in the past decades in several countries associated with demographic, economic, social and epidemiological factors (96). Details on the patterns of intake and secular trends, as far as they are available for individual countries, reveal that eating behaviour is quite labile and subject to dramatic changes within decades (97). A series of factors favour these changes, such as variations in family income, rural-urban migration, increase of tertiary activities related to foods and exposure to commercial propoganda (98). The first two factors induce changes in the food pattern while the last two guide the consumer to certain food products (98). Changes in food habits and in food consumption patterns are driven by a certain socio-demographic process which cannot be stopped (98).

Beyond infancy, in a child's preschool years, the diet diversifies as additional foods are incorporated into the diet, and as the child develops, changes in both portion sizes and the types of foods eaten may lead to changes in nutrient intake (99). Methods of assessing change in the habitual diet of children are essential for diet intervention studies as well as clinical management (100).

These changes have, and can, possibly only be assessed through national cross-sectional

surveys, such as those done in the United States - the Ten-State Nutrition Survey (101), the National Food Consumption Survey (NFCS) for 1977-78 (102) and the National Health and Nutrition Examination Surveys (NHNES I, II and III (103-106); and on a smaller scale through longitudinal studies such as the Bogalusa Heart Study, also in the US, that has reported trends in nutrient intakes of infants, children, and adolescents based on data collected for more the 20 years (107-109).

Longitudinal studies are particularly suited for studying diet/disease relationships over time at both the population and individual level. The Birth-To-Ten (BTT) Study in South Africa, on which this thesis is based, is such a longitudinal study.

3.1.1 The nature of longitudinal studies

3.1.1.1 Definitions for longitudinal studies

There are at least four possible definitions of a "longitudinal study", but regardless of any definition the fundamental components of a longitudinal study are that:

1. data are collected for two or more distinct time periods
2. the subjects are the same or comparable from one time period to the next and
3. data are compared between or among time periods in the analysis (110).

According to the first and most widely used definition, a longitudinal study is considered synonymous with a cohort or prospective study (111,112). A cohort study is an observational study of individuals selected without reference to presence or absence of disease. The objective of cohort studies is to assess how exposures to situations,

environments and things such as diet influence the risk of developing a disease or condition over time, such as dental caries.

The second definition is narrower in scope than the first. According to this only studies in which both the exposures and outcomes are measured repeatedly over time in the same individual are longitudinal studies (113). When diet is measured repeatedly over time in the same individuals as an exposure or an outcome, it is possible to investigate what factors contribute to changes in diet over time; how changes in diet over time affect the risk of disease; or how changes in diet over time affect the development of disease, dental caries for instance.

A third definition includes both observational and experimental studies where replicate measurements are made over time in the same individuals (110).

Finally, a fourth definition is that any study in which data are collected or analysed over time is considered a longitudinal study (110). In this definition repeated measurements are made in the same subjects or in comparable ones and would include studies in which the focus is on populations instead of individuals. Using this very general definition the term "longitudinal study" includes periodic cross-sectional studies. The advantage of this last definition is that it recognises the fundamental similarities among all longitudinal dietary studies related to measurement of food and nutrient intake (114). Data from periodic cross-sectional studies can, however, only indirectly study the effects of changes in dietary patterns on changes in dental caries incidence. It is clear that researchers must know these

definitions and their implications in undertaking longitudinal studies.

Longitudinal studies are, however, limited with regard to dietary changes among preschool children (99) and the tracking of intake of nutrients during childhood (115), in both developed and developing countries. This is due to several factors; cost, manpower and long term subject participation, to name a few, that hamper the assessment of nutrient intakes in this age group (99).

Studies have been conducted in countries showing change in nutrient intake over time among the same individuals in a community and area at different ages (116-123), while others have been conducted in the same area among individuals of the same age group within a particular community (107,109,124,125)

3.1.2 Data on dietary change from the Americas

Dietary intake data have been collected from US children in both large nationwide surveys and smaller longitudinal studies (86,107,126-132). Despite some survey design differences there are consistent trends in children's current intake and eating pattern.

Total energy intake of US children has increased or in some cases remained stable, whereas energy intake per kilogram body weight has decreased.(125,126,133). The percentage of energy from protein and carbohydrate has increased. In contrast, the percentage of energy from total fat has decreased from 38% to 33%. (104,126,133). A meta-analysis (134) of collated individual assessments of fat intake over the past century in the US showed that fat,

as a percentage of total energy, declined from a plateau of 40-42% in the 1950s and 60s to 36-37% in the 1980s, the beginning of the decline occurring in the mid 1960s.

Trends in the nutrient intake of 10-year old children are consistent with the national trends in the food supply and trends in the types of foods consumed by children (135-137). In the Bogalusa Heart Study (107) there was an overall decline in the total amount of milk, vegetables, soup, bread, grains and eggs consumed, with an increase in the total amounts of fruit and fruit juices, carbonated beverages, poultry and cheese. The percentage of total fat from milk, fats/oils, pork , eggs and desserts had decreased, while the percentage from poultry cheese and snacks had increased. Between 1977 and 1994 milk consumption declined by 24% for boys and by 32% for girls aged 6 to 11 years (138). During the same period there were changes in the type of milk children consumed with the proportion of children drinking reduced fat or fat-free milk doubling since the 1970s. By 1994 these milk categories were consumed more frequently than whole milk (139). Other shifts in food consumption included a decrease in egg consumption and an increase in consumption of poultry and substitution of margarine for butter (107,135,138). There has only been a change noted in the types of fruit juice consumed from orange juice being the most popular to apple juice now being the juice of choice (140).

Tracking is a term used to indicate the likelihood of a child to remain in a respective rank for nutrient intake in relation to his or her peers. Several studies have examined the nutrient intake of children at 2, 3 and 4-years and compared them with their intakes in subsequent years to determine if nutrient intake tracked over time (115,141). As early as 1961 Beal

(142) described tracking of nutrients among 38 upper middle class children aged 3-8 years in Colorado in the United States but the extent of tracking was however not quantified.

Data have suggested that tracking nutrient intake began in children as young as 3 to 4-years (115). One study showed that 36-57% of children in the highest quintile of fat intake at 3 to 4-years remained in that quintile at 5 to 6-years and 57-86% remained in the top two quintiles (115). Milk consumption during childhood can also track over time affecting lifetime milk consumption (143).

3.1.3 Data on dietary change from European countries

The Data from studies in Europe (75,119,144-146) have also indicated that diet changes over the years. Protein, total fat and energy have increased over the past 50 years, 1940-1988; carbohydrate intake has remained stable. The energy contribution from carbohydrate has decreased while that from fat has increased over this time, in contrast to that in the US (144). However, among the Eskimos the proportion of carbohydrate increased and protein reduced between 1955/57 and 1965, particularly among the younger age groups (147). Recently a similar meta-analysis to that in the US was conducted in the UK also showing trends in individual fat consumption between 1900 and 1985 (145). From a total of 97 studies with figures for individual fat consumption, 19 included children. Results showed that fat represented 30% of the total energy intake until the 1930s when it began to rise until the late 1970s, the trends being similar for all age groups (145). Since 1970 sugar and starch intake has declined in the UK, resulting in the fat intake to remain high at 42% of the energy intake, but the ratio of polyunsaturated fats to saturated fats doubled to 0.37 (146).

3.1.4 Data on dietary change from developing countries, Africa

In developing countries such as those in Africa there is even a greater paucity in the information available on change in nutrient intake over time. Longitudinal nutrition information depicting dietary changes over time among preschool children is lacking in South Africa, but information is available on dietary intake at a particular point in time (148-153). Although nutrient intake data have been collected in several South African studies no national survey and no longitudinal nutrition survey on preschool children had been conducted in South Africa until 1990 with the commencement of the BTT Study (154).

South African society is characterised by a population structure in which cultural and socio-economic factors probably influence eating patterns and therefore nutrient intakes. This country, like many others, is experiencing a process of urbanisation which is characterised by a nutrition transition (154), with the most dramatic changes having taken place in the past decade. These have been so substantial that dietary intake must have been affected, with the greatest changes possibly occurring in the country's largest metropolitan area and economic centre, the Johannesburg/Soweto area in the Gauteng province, previously the Transvaal. In the light of the likely changes it is not sensible to rely on the results of previous nutritional studies. There is a need for current information to assess both the existing and future health needs of all South Africans, but the realities of life in South Africa are that general population surveys of young children are impossible to do (41). Even the National Oral Health Survey of the Department of Health (155) was limited to children attending schools in metropolitan areas. The need for scientifically conducted surveys on the

food and nutrient intake of the South African population was recognised by the National Nutrition Research Institute (NNRI) of the South African Council for Scientific and Industrial Research (CSIR) as early as 1959 (153). At the time it was suggested that dietary surveys, especially on infants and young children, should be carried out regularly, particularly with the changing society and altered food habits, nutritional problems and the demands of professional practices (148,153). To make up for past inequities in South Africa and to allow for future developments many more demands are being placed on the national health care budget that can be satisfied (156). In such circumstances it is obvious that those most at risk to disease be targeted to make best use of available resources and regular surveys are necessary for this.

The food supply in most developed and developing countries is constantly changing and expanding and with the increasing effort to encourage populations to change their eating patterns it may be necessary to include the periodic assessment of diet at regular intervals during studies where the principle focus is on the effect of diet on risk of disease as well as identifying the individuals at risk of developing disease. Dietary patterns are very likely to change among ethnic subgroups as a result of cultural assimilation. Therefore periodic assessment is especially necessary with these subgroups to assure the validity and acceptance of the results from future cohort studies.

3.2 Methods

3.2.1 Descriptive statistics

To compare change in dietary intake, in the same community, area (Johannesburg/Soweto

in Gauteng) and age group, the dietary intake (mean and median values for energy, macro- and micronutrient intake) of all the 1995 5-year-old urban black South African children [n=1096] was compared to 5-year-old urban black children studied in 1984 in the same area [n=461], known then as the Transvaal. The nutritional data for 1984 and the SAS nutritional sums data from 1995 was merged to form one large data set and statistical analysis was carried out on this data set. Table 3.1 shows a summary of the subjects and methods for 1984 and 1995.

3.2.2 Analytical statistics

The data were first tested for normality with the Shapiro-Wilk Test (157). All the data were not normally distributed therefore non-parametric statistics (Wilcoxon and Kruskal-Wallis Tests) were used to compare values between the two years. The mean intake of macro- and micronutrients were compared with the 1989 Recommended Dietary Allowances (RDA) (158) for 4-6-year-olds and the percentage of children that fell below the RDA was calculated. Percentage change in mean macro- and micronutrient intake from 1984 and the 95% confidence intervals of the % change was calculated.

Table 3.1 Summary of subject sample and method

	1984	1995
Population	4 and 5-year-olds: rural black, urban black, Indian and white	5-year-olds: urban black, "coloured", Indian and white
Numbers	Equal numbers selected from each community, about 700 each	Each community selected as a representative proportional sample of the South African population
Area	All 4 and 5-year-olds studied from local health authorities: Johannesburg/Soweto - urban communities Bophuthatswana - rural community	Only children born between 23rd April and 8th June 1990 Johannesburg/Soweto - urban communities no rural communities studied
Dietary method	Dietary history amounts recorded in household measures and converted to g/day foods coded onto computer coding forms (MRC 1986 Tables) modified version of MRC dietary analysis programme to determine daily mean nutrient intake for each individual SAS used for statistical analysis	Food frequency questionnaire standard portions used based on: -i)(NRIND) Food Quantities Manual - ii) portion size questionnaire foods coded onto computer coding forms (MRC 1991 Tables) daily amount consumed calculated from intake frequency and our nutrition programme was used to determine daily mean nutrient intake for each individual SAS used for statistical analysis

3.3 Results

3.3.1. Mean energy, macro- and micronutrient intake in 1984 and 1995

3.3.1.1 Energy and macronutrients

The diets of all 461 5-year-olds were analysed from the 1984 data and all 1096 5-year-olds from 1995. Table 3.2 and Fig.3.1 show the mean daily energy and macronutrient intake of the children. The Kruskal-Wallis and the Wilcoxon Tests showed a highly significant difference in all macro- and micronutrient intake between 1984 and 1995, with the probability $P<0.0001$ for all nutrients except for potassium and copper which were $P<0.0207$ and $P<0.0124$, respectively. The intake of energy and all macronutrients was higher in 1995 than in 1984. Energy increased from 1558 kcal/day in 1984 to 2095 in 1995. Protein increased from 47g to 57g/day, as did total available carbohydrate and added sugar, but fibre was almost the same for both years.

The childrens' energy intake fell below the Recommended Dietary Allowances (RDA) of 1800kcal/day for 4-6-year-olds (158) in 1984 (1558kcal/day), meeting 87% of the RDA, but exceeded this recommendation in 1995. Protein exceeded 100% of the recommended 24g/day for 4-6-year-olds for both years. The childrens' fat intake almost doubled from 52g/day in 1984 to 95g/day in 1995.

In Tables 3.2 and 3.3 the 95% confidence intervals have been rounded to one decimal place except for single digits where two decimal places have been used.

Table 3.2 Daily mean, [95% confidence intervals of % change in means] and % change in means for energy and macronutrient intake of 5-year-old urban black South African children

Nutrient	5-year-old children		% change	RDA
	1984	1995		
number	461	1096		
energy (kcal)	1558	2095	+34.5 [34.4-34.5]	1800
protein (g)	47	57	+21.3 [21.0-21.5]	24
fat (g)	52	95	+82.7 [82.3-83.0]	
tot avail carbohydrate (g)	220	259	+17.7 [17.6-17.8]	
fibre (g)	16	18	+12.5 [12.1-12.9]	
added sugar (g)	63	76	+20.6 [20.4-20.9]	

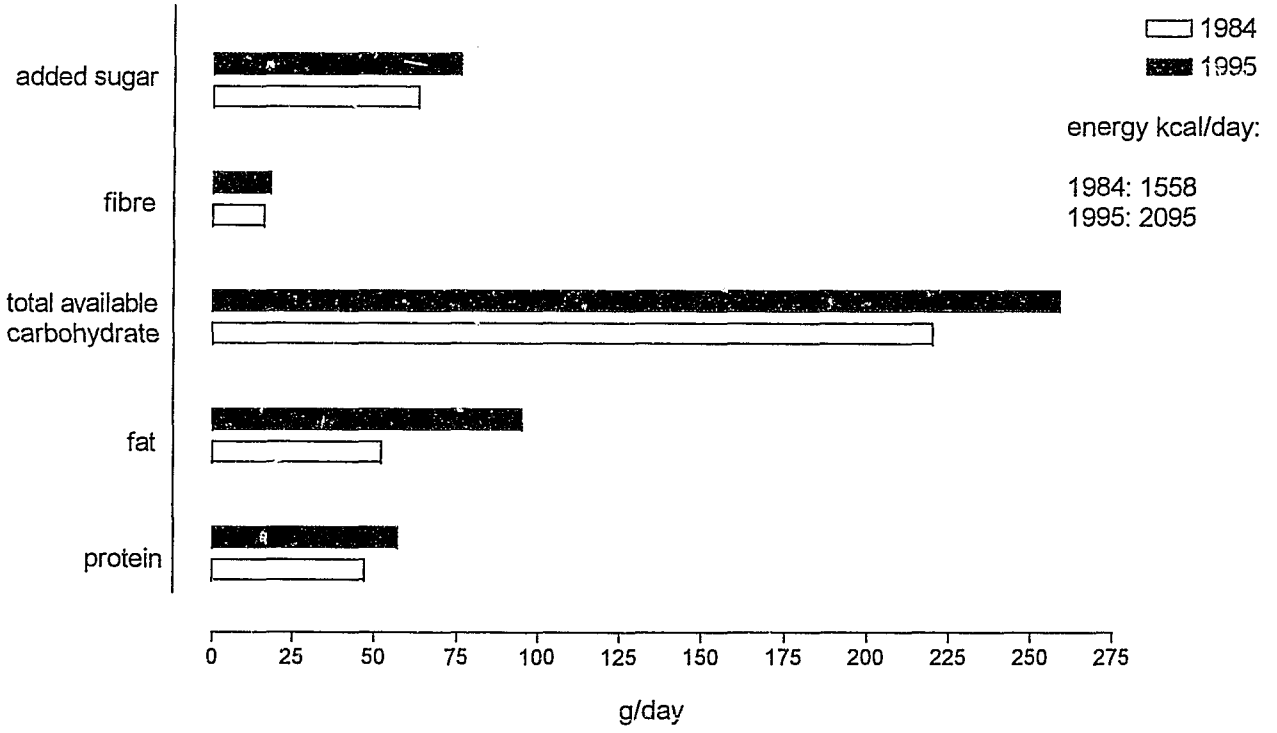


Fig.3.1 Mean daily macronutrient intake of 5-year-old urban black South African children in 1984 and 1995

3.3.1.2 Micronutrients

The intake of most micronutrients (Table 3.3 and Fig.3.2) by the children were similar or higher in 1995 compared to 1984, except for vitamin A, 864 RE/day in 1984 and 553 RE/day in 1995 and ascorbic acid, 60mg/day in 1984 and 50mg/day in 1995. There were also slight decreases in iron and copper from 1984 to 1995. Calcium, iron, zinc, vitamin D, nicotinic acid and biotin for both 1984 and 1995, and vitamin B6, pantothenic acid and vitamin E for 1984 fell below the RDA. The intake of all these micronutrients, however, met 67% or more of the RDA, with biotin being the lowest in 1984 meeting 60% of the recommended 25μg/day. Dietary vitamin D was an exception with the dietary intakes only meeting 10 and 30% of the required 10μg/day for the 1984 and 1995 studies, respectively.

3.3.2 Percentage of children below the Recommended Dietary Allowances (RDA) in 1984 and 1995

Among the macronutrients only energy and protein have RDA values therefore only the results of the RDA in relation to the micronutrients will be discussed in this section.

The mean intakes did conceal the fact that a high percentage of children fell well below the RDA for most micronutrients in both 1984 and 1995 (Table 3.3 and Fig.3.3). Over 90% of the children had intakes below the RDA for iron, zinc, copper, pantothenic acid, biotin and vitamin D in 1984 and for iron, zinc, copper and vitamin D in 1995. A high percentage, more than 80%, met the required intakes for magnesium, potassium, sodium and folic acid in 1984 and 1995; for vitamin A in 1984 and for phosphorus, vitamins B6, and E in 1995. For most nutrients; in particular phosphorus, vitamin B6, folic acid, pantothenic acid, biotin

and vitamin E, a lower percentage of children had intakes below the RDA in 1995 than in 1984. The percentage of individuals with intakes below the RDA for magnesium, potassium, zinc, copper, and vitamin D were similar for 1984 and 1995, all children being 100% below the RDA for vitamin D for both 1984 and 1995. A higher percentage of children had intakes below the RDA for iron, potassium, vitamin A and ascorbic acid in 1995 than in 1984. In general, a higher percentage of 5-year-old children in 1995 met the RDA for most nutrients compared to 5-year-olds in 1984.

Table 3.3 Daily mean, [95% confidence intervals of % change in means], % change in means and % below the RDA for micronutrient intake of 5-year-old urban black South African children

Nutrient	5-year-old children		% change	RDA	% children below RDA	
	1984	1995			1984	1995
calcium (mg)	528	651	+23.3 [23.2-23.4]	800	87	76
iron (mg)	8.0	7.5	-6.3 [-6.73–5.7]	10	83	90
magnesium (mg)	226	276	+22.1 [22.0-22.2]	120	2	1.0
phosphorus (mg)	827	1048	+26.7 [26.7-26.8]	800	52	20
potassium (mg)	2074	2151	+3.7 [3.68-3.75]	1400	6	8
sodium (mg)	1172	1923	+64.1 [63.0-64.1]	300	1	0
zinc (mg)	6.8	7.3	+7.4 [6.79-7.92]	10	93	94

Table 3.3 (continued) Daily mean, [95% confidence intervals of % change in means], % change in means and % below the RDA for micronutrient intake of 5-year-old urban black South African children

nutrient	5-year-old children		% change	RDA	% children below RDA	
	1984	1995			1984	1995
copper (mg)	1.0	0.9	-10.0 [-11.2--8.6]	1-1.5	92	95
vitamin A (RE)	864	553	-36.0 [-35.9--35.8]	500	13	44
thiamin (mg)	1.0	1.0	0 [-1.76-+1.77]	0.9	34	25
ribo ıavin (mg)	1.1	1.2	+9.1 [7.10-11.09]	1.1	54	42
nicotinic acid (mg)	10.5	11.3	+7.6 [7.09-8.14]	12	72	63
vitamin B6 (mg)	0.9	1.4	+55.6 [53.1-58.1]	1.1	80	21
folic acid (μg)	125	188	+50.4 [50.1-50.7]	75	5	1

Table 3.3 (continued) Daily mean, [95% confidence intervals of % change in means], % change in means and % below the RDA for micronutrient intake of 5-year-old urban black South African children

nutrient	5-year-old children		% change	RDA	% children below RDA	
	1984	1995			1984	1995
copper (mg)	1.0	0.9	-10.0 [-11.2--8.6]	1-1.5	92	95
vitamin A (RE)	864	553	-36.0 [-35.9--35.8]	500	13	44
thiamin (mg)	1.0	1.0	0 [-1.76-+1.77]	0.9	34	25
riboflavin (mg)	1.1	1.2	+9.1 [7.10-11.09]	1.1	54	42
nicotinic acid (mg)	10.5	11.3	+7.6 [7.09-8.14]	12	72	63
vitamin B6 (mg)	0.9	1.4	+55.6 [53.1-58.1]	1.1	80	21
folic acid (μg)	125	188	+50.4 [50.1-50.7]	75	5	1

Table 3.3 (continued) Daily mean, [95% confidence intervals of % change in means], % change in means and % below the RDA for micronutrient intake of 5-year-old urban black South African children

nutrient	5-year-old children		% change	RDA	% children below RDA	
	1984	1995			1984	1995
ascorbic acid (mg)	60	50	-16.7 [-16.8--16.3]	45	45	68
pantothenic acid (mg)	2.8	3.4	+21.4 [20.4-22.5]	3-4	89	55
biotin (μg)	15	21	+40.0 [39.5-40.5]	25	97	70
vitamin D (μg)	1.0	3.0	+200.0 [193.6-206.4]	10	100	100
vitamin E (mg)	6.5	18.2	+180.0 [177.3-182.7]	7	68	10

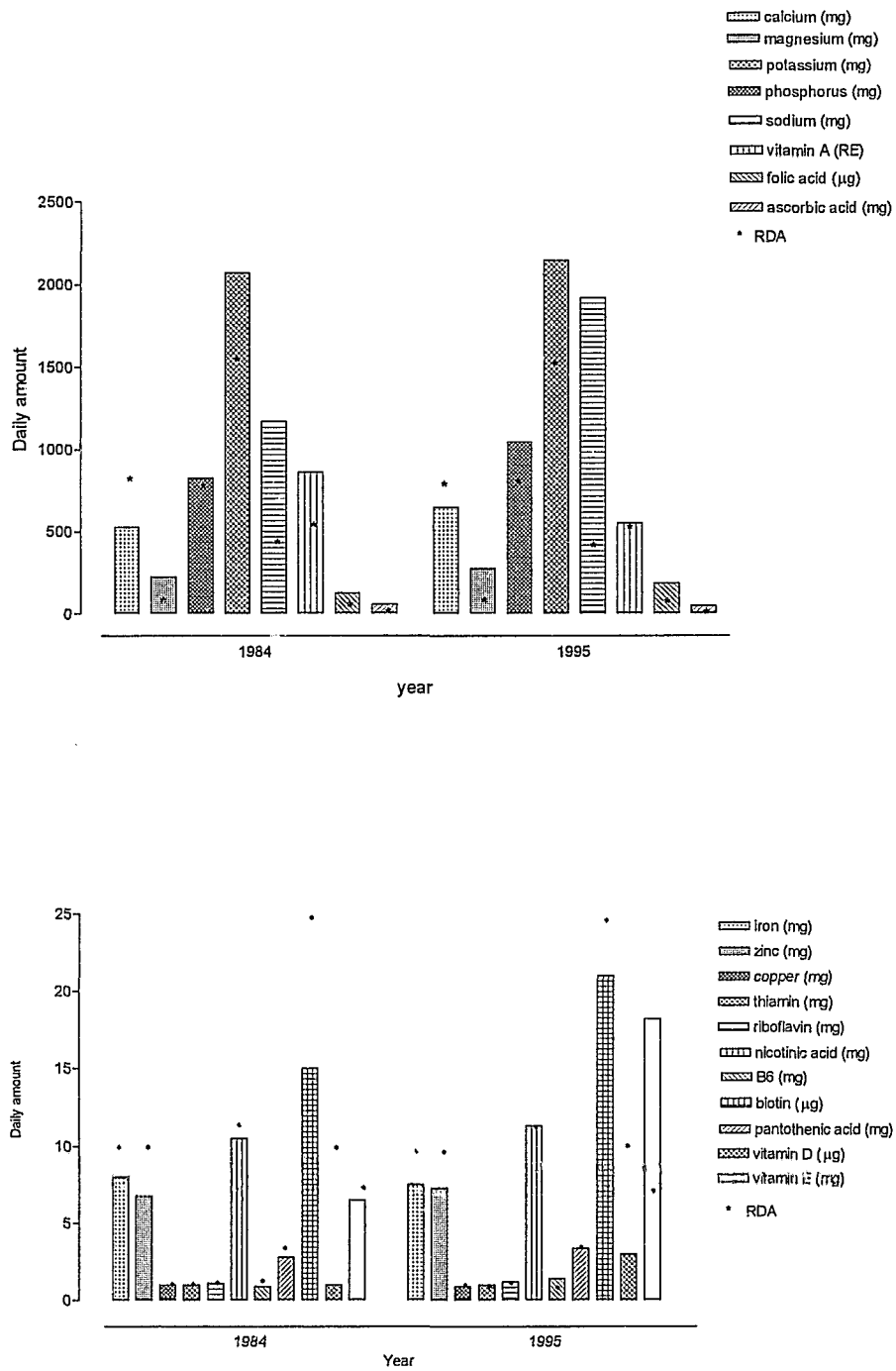


Fig.3.2 Mean daily micronutrient intake of 5-year-old urban black Soiuth African children in 1984 and 1995

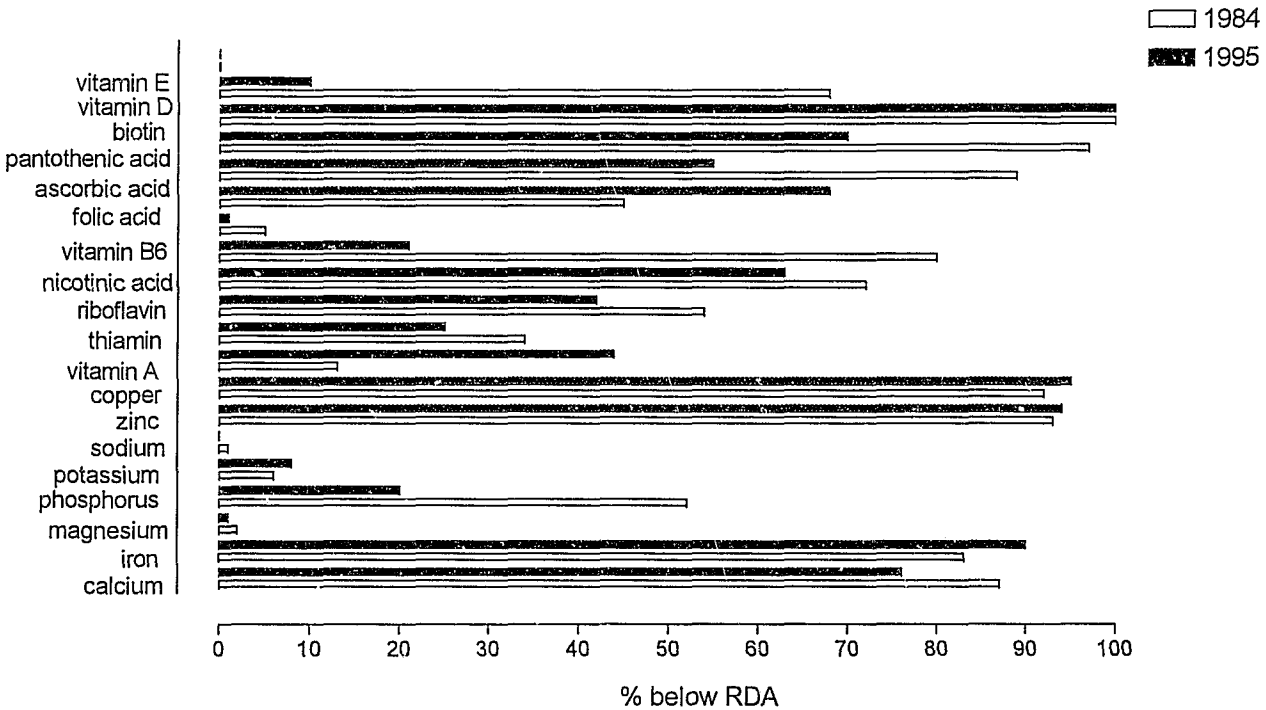


Fig.3.3 Percentage of 5-year-old urban black South African children below the RDA for micronutrient intake in 1984 and 1995

3.3.3. Percentage change in mean energy, macro- and micronutrient intake from 1984

3.3.3.1 Energy and macronutrients

Percentage change for energy and all macronurients increased from 1984, with fat showing the highest percentage change (82.7%), resulting in a percentage energy change of almost 35%. Fibre on the other hand showed the lowest percentage change of 12.5% (Table 3.2).

3.3.3.2 Micronutrients

The highest percentage change in means from 1984 to1995 was for vitamin D and vitamin E, 200 and 180%, respectively. Iron, copper, vitamin A and ascorbic acid intakes declined from 1984 to 1995, indicated by negative percentage changes in means, while potassium, zinc, thiamin, riboflavin and nicotinic acid showed less than a 10% change from 1984 (Table 3.3 and Fig.3.4).

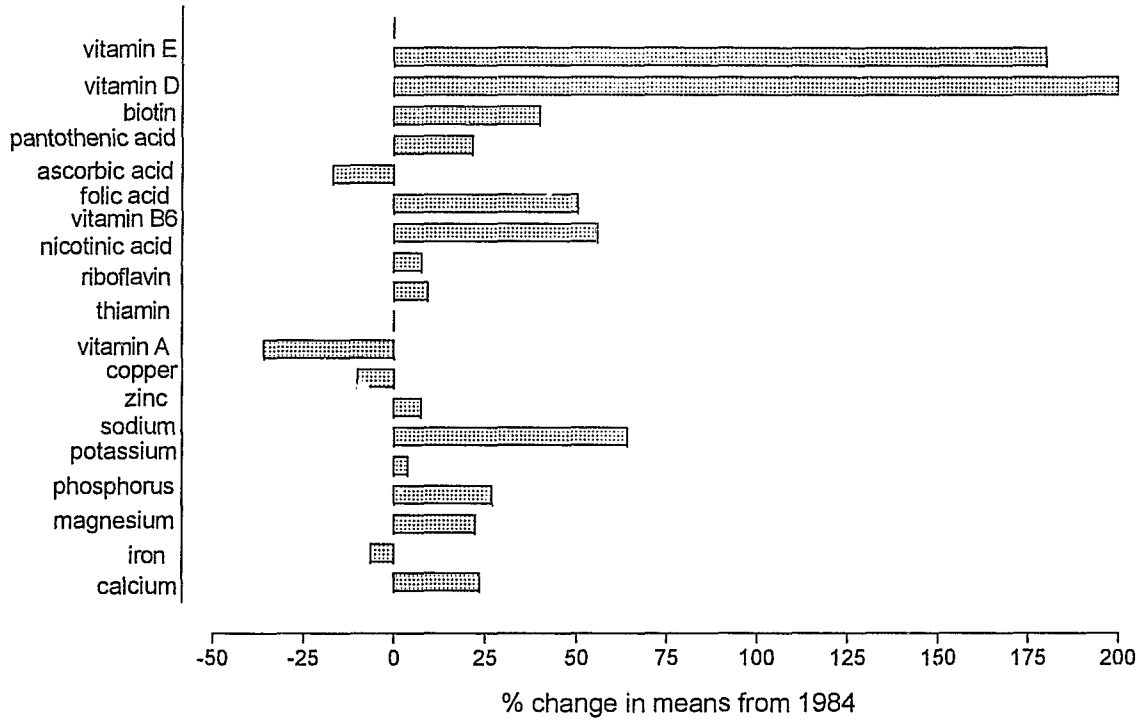


Fig.3.4 Percentage change in mean micronutrient intake from 1984 of 5-year-old urban black South African children

3.3.4. Percentage of energy from total protein, fat and carbohydrate in 1984 and 1995

Protein contributed almost the same percentage for both years, 12 and 11% respectively, but total carbohydrate decreased from 61% in 1984 to 52% in 1995 and fat increased from 30% to 41%. The diet consumed by the 5-year-olds in 1984 seems to meet the requirements of a healthy lifestyle, with fat contributing under 30% of total energy intake, the suggested upper limit being between 30-35% (7), but by 1995 a typical westernised diet was being consumed by 5-year-olds, high in fat and low in carbohydrate.

3.4 Discussion

3.4.1 Main findings

Dietary intake of energy and most macro- and micronutrients has increased over the past decade among South African children of the same age group, community and living in the same area, the Gauteng province of South Africa. The profile of the dietary intake in 1984 was typical of the prudent diet, high in carbohydrate and low in fat, whereas by 1995 a typical westernised diet was being consumed.

3.4.2 Methodology

A survey of the South African literature showed that most studies on large groups after 1979 utilised the 24-hour recall method. Before 1979, and on smaller studies after 1979, variations of a dietary history method or a food frequency questionnaire were used (154). Although different assessment methods were used in 1984 and 1995 explaining, at least partially, the difference in nutrient intake over the decade, both the dietary history and the food-frequency have been shown to overestimate food intake (159). However the degree of

overestimation depends on the number of food groups and food types in the questionnaire (160) which differed between the methods used. Most South African nutrition studies on preschool children have used either a dietary history (73,152,153) or a 24-hour recall (161,162) or a combination of both (163,164) but, only Rich 's study (154) reported the results for each method separately, intakes being generally higher for the dietary history. Besides the BTT Study a food-frequency questionnaire has only recently been used on South African rural black preschoolers in the Bloemfontein district, Free State province of South Africa (165), together with a dietary history, and for preschoolers at the Child Health Clinic at Bishops Lavis in Cape Town (166), together with a 24-hour recall. The results of these studies were, however, not reported separately. It has been suggested that a combination of methods provides more useful information than a single method (160), but this is not practical in large-scale studies such as these reported, and hence only single methods were used in these studies.

Not only have dietary methods differed in South African nutrition studies on preschool children but communities, specific age groups and environments have also varied. In addition different food composition tables were used for coding the data from 1984 and 1995. It is obvious that the nutrient composition of certain foods would have changed as well as food codes and new food items included in the tables during this time. This could have largely affected the difference in nutrient intake between 1984 and 1995. In South Africa and other developing countries in Africa, no national dietary surveys have been conducted on preschool children to assess change in dietary intake over time. Thus absolute or direct comparisons cannot be made between the present studies and others conducted in

South Africa or elsewhere in Africa.

3.4.3 Comparison with other South African studies

The South African National Survey Study Group (SANNSS)(154) analysed the literature available on the nutrient intake of South Africans and compiled a meta-analysis of the literature which seemed to be the most generalised information with which to compare the results of the 1984 and BTT studies. In that report data from 55 studies done after 1979 using the 24-hour recall method met the inclusion criteria and were combined. For energy and most macro- and micronutrients the intakes for the 2-5.9-year-old urban black children in the SANNSS were lower than that found in the 1984 and BTT studies. Only ascorbic acid intake (55g/day) was higher than that for the BTT children (50g/day) but was still lower than the 60g/day intake in the 1984 study. Calcium, iron zinc and nicotinic acid were the common nutrients found to be deficient, failing below the RDA, in the SANNSS,1984 and BTT studies. Maize is the staple diet of black South Africans and is a very poor source of nicotinic acid and this possibly explains the low intake of this nutrient. The SANNSS showed relatively low intakes of sugar(39g/day) in comparison to the 1984 (63g/day) and BTT studies (76g/day). As the 24-hour recall underestimates nutrient intake this would explain, partially at least, the lower intake of nutrients found in the SANNSS. It is clear though that the nutrient intake data of South Africans is fragmented and incomplete.

The main finding in the 1984 and 1995 studies was the high fat intake of 5-year-old urban black children in 1995 and the increase in this nutrient over the past 11 years. This will ultimately affect the children's mortality and morbidity in later years. As different dietary

assessment methods were used in 1984 and 1995 it cannot be confidently stated if there was an absolute increase in fat intake over the years or whether variation in dietary methodology accounted for the high intake. Although variations due to assessment methods cannot be ruled out, as mentioned previously, South African nutrition studies among urban black children over the years have shown an increase in fat intake between 1973 and 1995 (149, 152,153,161-164) irrespective of the assessment method used, although age groups have differed slightly. Fat contributed only 17% in 1973 (153), very much in line with the prudent diet, and rose to 41% by 1995.

With easier accessibility to food and services over the years, and improved socio-economic conditions a more westernised lifestyle is being followed by the urban black community and this is reflected in their nutrient intake, particularly the relative contribution of energy supplying nutrients.

Protein intake has been above the RDA for preschool children in most of the South African nutrition studies over the years and has also shown a constant contribution, between 11-14%, of total energy intake.

Broad comparison of the results of our studies with others conducted on young urban black South Africans in the former Transvaal province ispossible. Lubbe (153) in 1973 reported 6- and 7-year-olds to have energy intakes (1579 kcal/day) meeting 79% of the RDAs, protein intake of 46g and fat and carbohydrate at 30g and 285g/day, respectively. A dietary history was used both in Lubbe's (153) and the1984 study and the energy and protein

intakes correlate well. However the fat intake in our study was higher and the carbohydrate intake lower than that reported by Lubbe. The BTT 1995 interception results generally showed higher intakes of energy and most reported nutrients than Lubbe's study (153).

Lubbe (153) found very low intakes of calcium, riboflavin, nicotinic acid, and ascorbic acid, not meeting 67% of the RDA. Both the 1984 and 1995 studies too showed low intakes of calcium and nicotinic acid, but their intakes exceeded 67% of the RDA. Other studies on South African preschool children have shown both adequate (165) and inadequate intakes of calcium (167-170). Riboflavin intake met the daily requirement for preschoolers in the 1984 and 1995 studies, in contrast to deficient intakes reported in other South African studies (153,167,171).

Iron intake exceeded 100% of the RDA in Lubbe's study due to the high intake of unrefined cereal products, but met 80% of the RDA for the1984 and 1995 studies. Recently Wagstaff *et al.* (172) studied iron status of under 5-year-old children in greater Johannesburg and Soweto and found the incidence of anaemia to be 9% in Johannesburg and 28% in Soweto. Low iron intakes are also prominent in other studies of preschool (151,168) and older children (168-170) in other parts of South Africa, but adequate intakes were reported for rural black children in Lebowa (171).

Zinc appears to have shown a deficiency in most of the South African nutritional studies (151,165-167). Hagman *et al.* (173) too found low zinc values among Swedish children and warned that there is a possibility that the RDA for zinc, as well as iron, may be too high. In

1989, revised RDA figures for zinc remained at 10mg. Iron intake was lowered from 15 to 10mg in the 1-3-year age group but remained at 10mg for the 4-6-year-olds. In the UK as well, zinc was one of the problem nutrients for children 1.5-4.5 -years (174).

Lubbe (153) found the main sources of ascorbic acid to be tomato and onion stew, cabbage, spinach, potatoes, pumpkin and mixed vegetables. The 1984 and 1995 studies showed an additional contribution of fruit and fruit juices, and possibly a more frequent intake of potatoes and vegetables, to the intake of this vitamin (not reported in this thesis). This possibly explains the adequate intake of ascorbic acid in our study in contrast to others reported (164-166,175). Vitamin A on the other hand has shown both adequate (165,166,168,171) and inadequate (153,167,169) intakes over the years. Amongst rural preschool children in the South Western Cape more ascorbic acid than vitamin A rich foods were consumed (151). The present study showed a decrease in vitamin A and ascorbic acid from 1984 to 1995. This could possible be due to a lower intake of fresh fruit juice, particularly orange juice, and vegetables such as pumpkin, carrots and spinach. A more detailed account of the individual food items consumed by the children in the 1984 study have been reported elsewhere (149,152). The top 5 food items consumed by percentage of total dietary intake were tea [18.2%], milk [14.2%], stiff maize meal porridge [8.9%], cooldrink [5.8%] and brown bread [5.6%].

The 1984 and 1995 studies showed a very low dietary intake of vitamin D, also found in rural black preschoolers in the Free State province (165). This could possibly be explained by the fact that data on the vitamin D content of some South African foods are not

available. In addition these values do not take into account the endogenous formation of this vitamin in the presence of sunlight.

The difference in vitamin E between 1984 and 1995 could be explained by the large increase in fat intake over this period. Fat from butter, margarine, eggs and oil is the main dietary source of this vitamin. It must, however, be stressed that high intakes of group means of certain nutrients, as found in the 1984 and 1995 studies, conceal the fact that a high percentage of children had intakes well below the RDA for many nutrients, and the adequate mean intake of most nutrients found should be interpreted with caution (151).

3.4.4 Comparison with studies in developed countries

Regarding developed countries, a meta-analysis (134) has recently been conducted whereby all individual assessments of fat intake in the US during the century have been collated and averages calculated for intakes of total fat and its constituents for each decade. The results showed that fat, as a percentage of total energy has declined in the US from a plateau of 40-42% in the 1950s and 60s to 36-37% in the 1980s, the beginning of the decline occurring in the mid 1960s. The pattern of fat intake in the UK (145,176) is quite different. Fat intake in the US was significantly higher than in the UK from the 1930s to 1950s. During the 1960s the levels were very similar but a decline has been seen in the US since midway through the decade. By 1992/93 however, in the UK the percentage of energy from fat had dropped contributing 36% for children 1.5 -4.5-years of age (174). Both the US and the UK show a change in diet closely associated with mortality change, and preceding it by a similar period of time, 4-5 years.

The percentage of energy from fat of urban black South African preschool children in 1995 seems to be at the plateau of 40-42% experienced in the US and the UK in the 1950s and 60s. The fat intake of rural black preschool children in Lebowa (168,171,175), former Ciskei (164), Venda (177) and the Free State province of South Africa (165) and black 3-6-year-olds in the Cape (162) still appears to be contributing a percentage of total energy fitting to a prudent lifestyle. Surveys in brazil, South America, (96) on the intake of macronutrients in urban areas have also shown a decrease of carbohydrate and an increase of fat contribution as sources of energy due to an increase intake of animal protein. Animal fats have also been substituted for vegetable fats.

Dietary recommendations given by different expert groups to improve the nutritional status of populations to prevent chronic diseases propose a reduction of fat and an increase in quantity of complex carbohydrates and fibre. Different age limits however have been set for implementing the recommendations especially those concerning the amount of fat (178). More often a low fat diet has not been recommended for children until the age of 2-years and above (179). According to the IUNS/WHO Worhshop Recommendations (179) after the age of 2-years a gradual transition to a low fat diet should take place as the children grow older. A reason for not recommending a low fat diet for young children is a suspicion that inadequate energy and nutrient intake might interfere with optimal growth and development. It is also possible that the amount of added sugars might become unnecessarily high in a low fat diet. However, great variation has been observed in the composition of preschool childrens diets. Some preschool children have been give a low fat diet without any harmful consequences (180).

Current data in developed countries on children's nutrient intake are limited to National surveys such as the Ten-State Nutrition Survey (101), the National Food Consumption Survey (NFCS) for 1977-78 (102) and the National Health and Nutrition Examination Surveys (NHNES I, II) (105,106); as well as small scale longitudinal studies such as the Bogalusa Heart Study that reported trends in nutrient intakes of infants, children, and adolescents based on data collected from 1973 to 1982 (107-109). The National Diet and Nutrition Survey (174) of children 1.5 to 4.5-years in the United Kingdom showed that the average energy intakes were slightly below the recommendations, while intake of protein and most micronutrients were above for most children. Total sugar intake in both the 1984 and 1995 studies was lower than for the National diet and Nutrition Survey being 63, 78 and 87g/day, respectively.

Albertson *et al.* (125) studied nutrient intakes of 2-10-year-old American children over a 10 year period 1978-1988, the same time span as our study. Energy, fat and total available carbohydrate remained constant and protein decreased slightly. There was, however, a shift in the form of carbohydrate, an increase in complex carbohydrate and a decrease in total sugar intake. In general the nutrient intake of these children decreased between 1978 and 1988. This is in contrast to the 1984 and 1995 studies that showed an increase in energy and most nutrients over a 10 year period, with the percentage change in means being higher than those reported by Albertson. In the 1984 and 1995 study, fibre (complex carbohydrate) remained constant, between 16g and 18g/day, and added sugar increased by 17%.

A more recent study in Brazil (96) on the changes in food consumption revealed the

principle tendency to decreasing consumption of staple foodstuffs (beans, rice, manioc flour), pork, meat, lard and butter, the replacement of beef with chicken and the increasing consumption of eggs, milk products and vegetable oils . Recent studies with adult and elderly population from Sao Paulo showed a reduction in the consumption of fatty fried foods and sugar and an increase in the consumption of fruits and vegetables.

In contrast to the 1984 and 1995 results, changes in diet in the Netherlands between 1987/88 and 1992, (181) a 4 year span, showed the mean energy intake to have decreased over this time. The average contribution of fat to energy intake was lower in 1992 (36.9%) than in 1987/88 (40.0%) whereas in 1992 more energy was obtained from protein and carbohydrate. The intake of dietary fibre and cholesterol was substantially lower in 1992 than in 1987/88 in contrast to a stable fibre intake in 1984 and 1995 for South African children. As to the micronutrients the mean intake of vitamin A was lower while the intake of thiamin and vitamin B6 was higher in 1992. The above differences were seen in almost all sex-age groups. It is clear that the average Dutch diet, like that consumed by 5-year-old urban black South African children in 1995, does not fulfill the criteria for a prudent diet and will most likely induce increased risk of some chronic diseases.

3.4.5 Recommended Dietary Allowances (RDA)

Most commonly the RDA (158) are used as a reference value for the daily intake (74,75). Comparison of nutrient intakes to the RDA is a practical screen to identify potential public health concerns (103). An individual's nutrient intake may be less than the RDA and yet may be adequate to meet their needs. For another individual the same intake may not be

sufficient (182). Scrimshaw (183) stated that even in population groups with average intakes well below the RDA may contain few individuals who are deficient in certain nutrients. If this holds true then children from the 1984 study whose energy and certain nutrients intakes were below the RDA may not be considered malnourished. In fact it was shown that 16.6% of the clinically healthy children were wasted and 15.2% stunted (2,73), based on the National Center for Health Statistics (NCHS) Standards (184). These children's mean heights and weights were very similar to American black preschool children (185,186). There are, however, no RDA specifically estimated for the South African population and thus to compare the energy and nutrient intake of these children with the American RDA will not give a true indication of their nutritional status. Most South African studies have used the RDA as a reference standard for nutrient intake and for comparison and for uniformity this was the reference choice for the present studies, even though the Dietary Reference Values have a better scientific basis. Published data (187-190) proposes that the current recommendations for energy should be re-evaluated as the requirements may be lower than the recommendations. Since the nutrient requirements vary considerably from one person to another, and since the needs of an individual are almost never known, it does not seem meaningful, or possible, to try to define a safe lower limit which cannot be determined scientifically with an acceptable degree of precision (187). With only a small percentage of the children from the 1984 study being wasted and stunted it would seem that the lower energy intake by this group was adequate for growth.

3.4.6 Conclusion

It must be emphasised that this study is specific to 5-year-old urban black South African children and cannot be extrapolated to other age groups, communities, and areas in South Africa or elsewhere. It is the black community in South Africa that has experienced the most dramatic changes over the past decade, including both social, political, economic and environmental and these changes have obviously been partially responsible for the changes in dietary intake between 1984 and 1995. This study has indeed shown that with these changes current reliable nutrition information is needed to assess both the existing and future health needs of all South Africans.

CHAPTER 4.

ENERGY, MACRO- AND MICRONUTRIENT INTAKE IN RELATION TO DENTAL CARIES AMONG 5-YEAR-OLD CHILDREN

4.1 Introduction

To understand how nutrients contribute to the enhancement of the resistance of the oral tissues to oral disease is one of the first findings about dental caries and nutrition that should be highlighted (26).

4.1.1 Development of dental caries

Dental caries is determined by an interaction of etiological factors; plaque bacteria, saliva minerals and trace elements and food residues, together with genetics, behaviour, age, education, health care availability and other factors supplied by the host, not forgetting the individual's susceptibility and resistance to caries development (191). The acidogenic theory of dental caries etiology is supported by experimental evidence. There is interaction of two variable factors, firstly those affecting a tooth's resistance to caries attack including the chemical, microstructural and morphological nature of the enamel surface and secondly the factors which determine the cariogenicity of a tooth's environment including diet, plaque and saliva (191,192). Dental caries is thus not determined by one or more factors independently.

Dental caries is consistent with an infectious and nutrition model of causality. The infectious and nutrition explanations being more consistent than the genetic explanations (193). It was

the work of Keyes and Fitzgerald that identified caries as a transmissible infectious disease (194,195) with a specific window of infectivity that corresponded with the eruption of teeth and the change from a milk to a solid diet (26). Diet and food residues contribute differently to implantation, colonisation and metabolic activity of oral cariogenic bacteria.

There is a strong belief that individuals are "more" or "less" susceptible to the development of dental caries depending on their resistance to infection (196). With an inadequate intake of nutrients resistance to infection is lowered and individuals become more susceptible to diseases, including dental caries. Resistance to disease may be altered by virulent microorganisms or bacterial endotoxins which alter the metabolic handling of minerals such as copper, iron and zinc, thereby indirectly affecting caries susceptibility (197,198). The fall in serum iron and zinc and the rise in serum copper is brought about by changes in the concentration of specific tissue proteins (197). Other micronutrients, selenium, vitamins A, E and B6, ascorbic acid and folic acid also have important influences on the immune responses.(199). If these nutrients (elements) influence the susceptibility to caries it would seem likely that they do so by altering the resistance of the tooth itself at the plaque tooth enamel interface (200). Malnutrition is the most common cause of immunodeficiency worldwide. Protein-energy malnutrition is associated with a significant cell mediated immunity. The deficiency of single nutrients altering the immune responses has been observed even when the deficiency state is relatively mild.

The relationship of individual macro- and micronutrients to the individual's susceptibility and subsequent development of dental caries will be discussed in more detail:

4.1.2 Evidence of energy and macronutrients in caries susceptibility

Local dietary factors, particularly the sugars, have usually been investigated as risk factors for caries, rather than general nutrition. This is exemplified by Burt *et al.*(201) through their longitudinal studies of sugar intake as well as by Ravald and Birkhed (202) and Holm *et al.*(203). Results have, however, been conflicting. Sreebny's (204) review reaffirmed a positive relationship between sugar intake and dental caries incidence, while Walker and Cleaton-Jones (205) identified several situations in the literature for which sugar alone did not explain caries incidence. Others (176,206,207) have shown that by decreasing sugar in the diet fat intake tends to increase, thus indirectly dietary fats may prevent the development of dental caries. There is a well established reciprocal relationship between the percentage of energy from sugar and that from fat. As the percentage of energy from fat increases that from sugar decreases (176,206-208). Some workers, however, have considered diet in a wider context, evaluating the nutritional quality of the diet as a whole using a quality index based on the eating frequency of foods divided into eight levels (209). Total energy intake is one way of understanding general dietary intake. Willett and Stamper (210) believe it has implications for the interpretation of other nutrients in epidemiological studies as well as being of intrinsic interest.

4.1.2.1 Energy and protein

Saliva plays a major role in the maintenance of oral health. Its volume and composition affect caries susceptibility and can be modified by nutrition, particularly the lack of protein. A lack of adequate protein also leads to a lower salivary flow and an altered salivary protein content, resulting in an increased susceptibility to caries both pre- and posteruptively (27).

The different degrees of protein-energy malnutrition have recently been reviewed (211) and a recent study (212) illustrates the importance of protein intake on saliva composition. The effect of chronic malnutrition on saliva secretion and caries susceptibility in children was investigated in another study done in India by Johansson and co-workers (213). A significant positive correlation was found between the degree of chronic malnutrition and impairment of chewing stimulated saliva secretion. With the decreased saliva rate the buffering capacity also decreased and more caries resulted.

It has been suggested that early malnutrition may also produce defects in the teeth during the period of development such that these teeth are more susceptible to subsequent dental caries after eruption (39,214). Fern *et al.* (215) indicated that even malnutrition of the mother while a child is in utero can result in enamel defects. Early malnutrition produces a delay in eruption and exfoliation of the primary dentition which significantly increases the rate of caries in both the primary and permanent dentition (214). During tooth development protein is essential for the correct formation of the enamel and dentine matrix, and it is thought that protein is associated with coating the enamel and hindering the dissolution process (216). Deficiencies occurring as part of malnutrition may bring about a reduction in tooth size and an increase in enamel defects (39). Studies by Shaw (217) and Holloway *et al.*(218) have shown, in animals, that protein deficiency is related to subsequent dental caries. Developmental defects have been recorded more frequently in primary teeth of low birth weight and premature infants than in full term infants (219) and enhanced caries susceptibility has been associated with neo-natal enamel hypoplasia of prematurely born children (220). In another investigation to evaluate the prevalence and distribution of

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developmental enamel defects in the primary dentition of Chinese children 3-5 years of age (221) those born prematurely were found to have four times more enamel lesions than full term children. However, there appears to have been very little epidemiological research on protein malnutrition and dental caries. Such work that has been carried out has focussed on very small numbers of premature infants and on immigrant groups of children living within western Europe coupled with the measurement of growth and development. While these immigrant children have high levels of caries there has been no research to indicate that this is related to nutrition but rather it has been described as dietary, resulting from frequent use of foods high in refined carbohydrate (39). It was found in Sweden (40) and Denmark (222) that preschool children with the highest caries prevalence came from refugee and immigrant communities (40).

Other studies have shown no relationship of energy intake to caries incidence (31,62,223).

4.1.2.2 Fat

Protein and fat were found to be associated with inhibition of caries in a series of experiments to test the relative cariogenic potential and to identify the major cariogenic elements in 22 popular snack foods in a rat model (224). The association of fat with low caries may be related to factors including its enhancement of food clearance (225), coating of the surface of the enamel in the same way to protein (226) and possible antimicrobial effects. Protein and fat together have been associated with a low caries incidence in nomadic Eskimos who consumed diets high in protein and as much as 65% fat (227).

4.1.2.3 Carbohydrate and sugar

The epidemiological evidence of the role of sugar in the aetiology of dental caries can be divided into observational and interventional studies. While there have been a large number of observational studies, few interventional studies have been conducted because of the difficulty in altering peoples diets over a long period of time. The evidence has not denied the importance of sugar in caries aetiology and many factors have to be taken into consideration with regard to the role of sugar in the etiology of dental caries, the amount consumed, the frequency of intake as well as the type of sugar consumed (68) and of the three variables amount, frequency and type of sugar, frequency and type of sugar are the most important (228). Over the years, however, the relative importance of these factors has changed. Recent reports have attributed a much less important role to carbohydrates; sugar consumption as a single factor no longer affects caries prevalences as much as it did in the past (68).

a) Observational studies

1. World-wide evidence associating mean sugar consumption with caries experience.

One indicator of the association between sugar intake and caries is the information provided by Marthaler (229) in which figures for annual sugar consumption per capita were compared with caries level in 11-12-year-old children from 19 countries. The close correlation between sugar consumption and caries experience is, however, only a crude indicator as the caries data applies specifically to 11-12-year-olds while sugar consumption data applies to all age groups.

2. Cross-sectional studies relating caries experience to the consumption of sugar and confectionery

Up to 1981 there have been at least 39 cross-sectional observational studies in several countries attempting to indicate whether a statistically significant relationship was observed between the individual's caries experience and their sugar or confectionery consumption. (230). Ten out of the 15 studies in young children found significant correlations between sugar frequency and caries experience but Woodward *et al.* (231) noted that when data from 29 industrialised coutries were analysed separately there was no evidence of a sugar-caries relationship. It should be stressed that whilst a few of these studies (those investigating sugar in infant feeding for example) attempted to assess lifelong habits of sugar consumption, nearly all the studies tried to relate lifetime caries experience to dietary habits measured over the previous few days. This approach may be acceptable for young children whose teeth have only erupted and become carious over the preceding few years and whose sugar eating habits may not have changed appreciably since the time the dentition erupted, although incremental studies should still be conducted so that caries development can be measured over the same time period which the diet is also assessed. Only one study (232), appears to have related caries increment with eating habits. Although they found some statistically significant correlations, the incremental period of 1 year is really too short for satisfactory comparisons. Therefore there is a need for studies which assess sugar-eating habits over a defined period of time and relate these to caries which develops over the same period (228). Being a longitudinal observational study the BTT Study has attempted to do this between 1991 and 1995.

b) Interventional studies

The two most important interventional studies are the Swedish Vipeholm Study (66) and the Turku Sugar Study from Finland (233). The Vipeholm Study (66) is probably the biggest study in the field of diet and dental caries ever undertaken. The subjects included adult mental defectives in an institution with controlled dietary intake and the results concluded that sugar taken only at meals, even in very high amounts, was not associated with high caries increment, but sugar taken both at and between meals was associated with a dramatic rise in caries increment.

The Turku Study showed that substitution of the normal Finnish diet of sucrose by xylitol was associated with a dramatic reduction in caries increment. However it could not be concluded that substitution of sucrose with fructose resulted in less caries (233).

Although the Hopewood House Study (69) is not an interventional study it is a longitudinal study that examined the association between diet and dental caries among children in an orphanage in New South Wales, Australia. Subjects consumed a strictly supervised controlled lacto-vegetarian diet that was virtually devoid of sugar and white flour. The children in the study had fewer dental caries in both the deciduous and permanent dentitions than children of the general population but, over the five year period of the study the number of caries free dentitions decreased among children in the study due to deviation from the lacto-vegetarian diet as they got older.

4.1.2.4 Fibre

The evidence of dietary fibre in relation to dental caries is very sparse but some studies have indicated that the mean number of decayed teeth is positively associated with fibre as well as with carbohydrates and sucrose intake (223) and dietary fibre together with potassium were the significant nutritional factors on total caries experience among junior high students in Korea (234).

4.1.3 Evidence of micronutrients in caries susceptibility

4.1.3.1 Trace elements

The discovery that ingestion of water-borne fluoride decreases the prevalence of caries among children led investigators into exploring the possible beneficial effects of other trace elements on caries. However, no consideration was given to the possibility that some trace elements may also enhance the development of caries (235). Since the early 1970s considerable evidence has been presented indicating that trace elements have shown both cariostatic and cariogenic properties (200). Navia (236) suggested a tentative classification of the trace elements into five groups according to their ability to promote or reduce caries in experimental animals. No doubt this classification may be challenged on the basis of many conflicting reports on practically all the mineral elements except fluorides and phosphates. However, it serves as a guide. The following table (Table 4.1) is an arranged list of elements in the order of cariogenicity with the elements that are thought to belong to each category according to Navia (236).

Table 4.1 Classification of trace elements according to their cariogenic potential (Source: Navia 1970) (236)

1. caries-promoting	selenium, magnesium, cadmium, platinum, lead, silicon
2. mildly cariostatic	molybdenum, vanadium, strontium, calcium, boron, lithium, gold
3. doubtful effect	beryllium, cobalt, manganese, tin, zinc, bromine, iodine
4. caries-inert elements	barium, aluminium, nickel, iron, palladium, titanium
5. strongly cariostatic	fluorine, phosphorus

Although several trace elements have been implicated for their possible role in dental caries, their mode of action can only be speculated on, even if a relationship is confirmed. The presence or absence of the respective trace elements in enamel above or below specified concentrations has to be considered as the potential means of influencing the caries effect. The deposition of elements in the enamel results from the uptake during mineralisation of the tooth or posteruptively (237).

Studies of caries prevalence and trace element content of enamel are few despite much discussion and speculation: only a small number of elements have been implicated as having a positive correlation namely manganese (Mn), copper (Cu), cadmium (Cd), aluminium (Al), iron (Fe), selenium (Se), strontium (Sr), arginine (Ag), tin (Sn), barium (Ba), lithium (Li) and lead (Pb). Of these only Sr, Se and Li appear to have sufficient evidence to

support their presence in enamel (237).

A summary of the data associating caries prevalence to the increased content of trace elements in the enamel is shown in Table 4.2

Table 4.2 Summary of reports on proposed associations between caries prevalence and trace elements content of enamel (Source: Curzon and Cutress 1983) (237)

Reference	Year	No. samples [Age group]	Trace element	Effect on caries of increased trace element content
1.Curzon & Crocker (USA) (238)	1978	451 [10-20 years]	Mn, Cu, Cd Al, Fe, Se Sr	increased decreased
2.Curzon & Losee (USA) (239)	1977a	208 [?]	Sr, Ag, Sn Al, Ba, Cu, Li, Zr	decreased increased
3.Curzon & Losee (USA) (241)	1977b	147 [11-19 years]	Sr	decreased
4.Retief *et al.* (SA) (242)	1976	20 [16-17 years]	Se	decreased
5.Brudevold *et al,* (244)	1977	251 [?]	Pb	increased
6.Schamschula *et al.* (Papua- New Guinea) (243)	1978	301 [16-18 years]	Li Pb	decreased increased
7.Vrbic & Stupar (Yugoslavia) (240)	1980	16 [?]	Sr	decreased

From the above reports increased concentrations of Cu in the enamel have been linked to an

increased relationship to DMFT (238,239) while increased concentrations of Se and Sr have consistently shown a negative relationship to caries (238-242). Increased concentrations of Al in the enamel has shown both a positive (239) and a negative (238) relationship to DMFT and three elements (Mn, Cu, Cd) have shown a positive relationship to DMFT (238). In two studies (243,244) Pb was also implicated with a contradictory role of both increasing and decreasing caries prevalence with increase in enamel content. Although Brudevold *et al.* (244) mentioned the possibility of Pb as a caries inducing agent, the enamel F levels of the high Pb group were higher than in the low Pb group.

Only a small number of elements have been studied for their presence in the enamel of the primary teeth, and the evidence suggests that Na, Cl, Mg, K, Zn, Pb, Ba, Cu and Fe occur at similar concentrations to those in permanent enamel. An exception appears to be Al, which on the basis of two studies (245,246) is present in higher concentrations in primary than in permanent enamel. However, in the two studies mentioned analysis of permanent enamel also revealed unusually high Al levels.

A number of studies over the past 30 years have indicated an association of trace elements intake to caries within Europe beginning with the early animal studies of Bertrand (247) and later studies using animals such as those of Buttner (248). European studies on many trace elements have shown both positive and negative relationships to dental caries (237), although there does not seem to have been any further work within the past 15 years.

a)Cariogenic elements

A series of regional epidemiological studies (235) conducted among 2069 Oregon children 14-16 years of age indicated that subjects living east of the Cascade Mountain Range were less susceptible to caries development than those to the west of the mountain. The same observation was made in a later study among groups of children living in the neighbouring state of Washington into which the Cascade Mountains extend. Fluoride content of the water supply, dietary habits, and other environmental variables were found not to be responsible for the geographic differences in caries rates found among these children. Consideration of the influence of selenium as a possible explanation for the variation was prompted by the results of previous studies of people living in the US where selenium toxicity was prevalent among farm animals and the soils and vegetation contained high amounts of selenium. The studies disclosed that one of the most frequent signs of disease seen among these people was a high caries prevalence. The results demonstrated a direct relationship between selenium intake and caries rates and the high caries rates were associated with increased amounts of selenium in the urine and vice versa. The selenium content of eggs and milk consumed by children in eastern Oregon was less than that of the same products consumed by children in western Oregon where the caries rates were high (235). It is thought that excessive selenium disrupts the enamel matrix and subsequent mineralisation of the tooth (249,250).

Minerals such as magnesium and manganese promote growth and multiplication of Streptococcus mutans by affecting the colonisation and growth of the oral bacteria posteruptively. On the other hand oleic acid is inhibitary (27).

Lead is one of the most toxic and pervasive pollutants in society and although there has been some lowering of blood lead levels in recent years the levels continue to be of concern for persons with low income and those with low education attainment. Notably these are the persons where the highest prevalence of dental caries is observed. Information relating to lead toxicity and oral health is sparse, but the preponderance of epidemiological data shows a relation between lead in the environment and the prevalence of dental caries. It was found that pre- and perinatal exposure of rats to lead resulted in 40% increase in the prevalence of dental caries and the lead levels in the milk from lead-treated dams were approximately 10 times as high as the corresponding blood levels (251). Lead ingested by a pregnant women or new mother may become concentrated in breast milk, leading to increased susceptibility to early childhood caries in nursing infants and toddlers. Lead and other heavy metals interfere with normal calcium metabolism and may affect salivary gland function, amelogenesis and dentinogenesis thereby leading to more caries. Lead in saliva and plaque may form lead fluoride, making fluoride unavailable for its usual anticariogeneic effects (252).

b) Cariostatic elements

Molybdenum was first associated with low caries prevalence in humans in Hungary (253) and also in England (254).

Deficiencies in calcium, phosphorus and iron have also all been linked to increased caries susceptibility (27).

Nutritional requirements vary during development of tissue and organs. Some nutrients like calcium and phosphorus (26,27) could influence enamel formation preeruptively and, if deficient together with vitamin D, increase the susceptibility to hypoplastic lesions (255,256). Posteruptively, it may effect alveolar bone resorption processes. Calcium release, which results from demineralisation of teeth, changes in the rate of salivary secretion and permeability of the blood-saliva barrier, and other factors may contribute to the redistribution of calcium fractions in the saliva, which plays an important role in the pathogenesis of dental caries (257). A series of experiments carried out to test the relative cariogenicity and major cariogenic elements of 22 popular snack foods in a rat model showed that phosphorus, calcium and fluoride in foods were all associated with inhibition of caries (223). The association of calcium and phosphorus with low caries in rats has been reported before (258). Additions of organic phosphates in combination with calcium to breakfast cereals was found to reduce bovine enamel solubility in streptococcal fermentation mixtures (259).

The concentration of water supplies taken from the homes or schools of caries-resistant navy recruits from northwest Ohio (USA) were compared with the content of public water supplies of the 7 largest cities in Ohio, the cities in states where dental caries prevalence was least and greatest (260). Statistical analysis revealed significant differences in the concentration of boron, lithium, molybdenum, and strontium and the suggestion is that these elements in conjunction with fluoride may be instrumental in reducing dental caries. There was some indication that the intake of trace elements was governed in part by choice of vegetables in the diet. While many elements were lost from green beans when cooked in

water from northwest Ohio, fluoride, lithium, molybdenum and strontium were taken into the vegetables in considerable quantities. The explanation for the number of caries resistant recruits from northwest Ohio may be in the simultaneous occurrence of elevated concentrations in water of at least boron, lithium, molybdenum and strontium with fluoride. Although strontium showed cariostatic properties in this study it did not show any effect on caries in a study in England (261).

Iron has shown signs of being an important factor in caries resistance pre-eruptively (27). Sintes *et al.* (262) showed that even a slight deficiency of iron during tooth formation in the rat predisposed the animals to more caries. Deficiencies in iron as well as zinc can influence the amount and composition of saliva, limiting the protective effects it has in the oral cavity (26). Sugar has been used as a vehicle for iron fortification in communities where anaemia is prevalent. Iron reduced the incidence of smooth surface caries at concentrations as low as 88ppm iron. In addition a combination of iron and fluoride reduced the incidence of caries (263). It was also found that combinations of copper, iron and fluoride with sugar may have the additive effect in reducing the cariogenic potential of sugar by affecting lactic acid formation and reducing bacterial colonisation in rats (264)

Copper is found in low concentrations in a wide variety of foods. There is abundance evidence that shows that copper inhibits SH-containing enzymes and may prevent acid production in dental plaque and caries in rodents (265). More recent evidence has demonstrated that inclusion of low levels of copper in sugar during the manufacturing process renders the sugar virtually non cariogenic (266). Clinical studies on the effect of

copper on caries incidence, however, are lacking (267).

4.1.3.2 Vitamins

a) Cariogenic vitamins

Of the B complex vitamins there has been some slight laboratory evidence that oral flora and hence dental caries incidence may be affected by dietary supplements (39). Nicotinic acid has been shown to promote the growth and multiplication of Streptococcus mutans and hence increase caries susceptibility (27). Another study among junior high pupils in the Kangwha county of Korea confirmed that DMFS scores were positively associated with nicotinic acid intake (234).

b) Cariostatic vitamins

Since the early studies of Mellanby (268) there has been an interest in Europe in the relationship of vitamin intake, as part of nutrition, and dental caries. Experiments on puppies indicated that vitamin D deficiency had an effect on calcification of the enamel. Subsequent studies reported positive effects of supplementing the diet with this vitamin but these were equivocal. No substantial epidemiological studies have been carried out in recent years and there is no evidence of caries-vitamin D relationship (39).

Vitamin A deficiency has also been linked to increased caries susceptibility (27). In the 1930s researchers knew that vitamin A deficient animals not only failed to grow, but were more susceptible to infections than well nourished controls. Such early animal experimentations and clinical observations provided important clues that vitamin A is

necessary in response to infection and may decrease the severity of infectious diseases (269). Vitamin A not only restores immunity in deficient humans and animals, in certain situations it can also stimulate immunity (270). In a study in Guatemala (35) the effect of caloric supplements in addition to retinol, ascorbic acid, vitamin A, nicotinic acid and thiamin resulted in a 50% reduction in linear enamel hypoplasia and showed that nutritional supplement of the diet early in life leads to a significant reduction in enamel hypopoasia.

A recent study carried out in Leeds, UK (271) used the National Diet and Nutrition Survey database of preschool children. Dmft, caries incidence and blood measures of red cell folic acid, vitamin B12 and ascorbic acid were available for 763 children aged 3 to 4 years. The incidence of caries was higher in children with the lowest blood levels of ascorbic acid and folic acid, with folic acid showing the most significant inverse trend with caries prevalence (271).

4.2 Methods

4.2.1 Dietary credibility of study samples

The data for the BTT 1991 and 1995 interceptions were first tested for normality with the Shapiro-Wilk Test (157). All the data were not normally distributed therefore non-parametric statistics (Wilcoxon and Kruskal-Wallis Tests) were used for comparison.

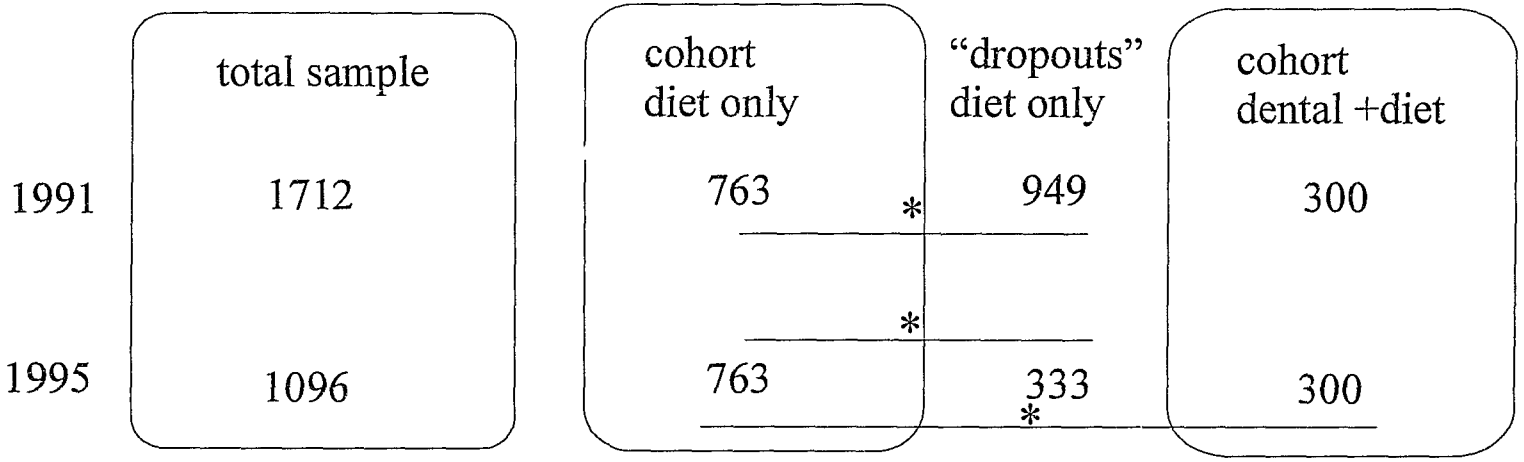
To test for the current study's dietary representativeness of the whole BTT population a series of three comparisons were done:

i. It was first established if those individuals that had dietary information for 1991 **and**

1995 **with or without** dental information for 1995 (longitudinal cohort n=763) were significantly different from those individuals that only had nutrition information for 1991 (1991 cross-sectional cohort n=949) and

ii. If those individuals that had dietary information for 1991 **and** 1995 **with or without** dental information for 1995 (longitudinal cohort n=763) were significantly different from those that only had nutrition information for 1995 (1995 cross-sectional cohort n=333).

iii. It was also determined if those individuals that had nutrition information for 1991 **and** 1995 **and** dental information for 1995 (longitudinal cohort n=300) were significantly different from those that only had nutrition information for both interceptions at 1991 and at 1995 (1991/1995 cross-sectional cohort n=463). It could thus be determined if the samples used were, or were not, nutritionally representative of urban black South African preschool children in Soweto. (See Fig. 4.1)



* comparison for credibility for representativeness

Fig.4.1 Subject numbers in data sets and "dropouts" in the 1991 and 1995 Birth-to-Ten (BTT) interceptions showing comparisons for credibility for representativeness

4.2.2 Data analysis principles to study the relationship between energy, macro- and micronutrient intake and dental caries among 5-year-old children

The first step in the analysis described only the dietary intake of the total sample of 1-year-old urban black South African children in 1991 [n=1712] and 5-year-olds in 1995 [n=1096]. A Proc Means and Univariate analysis determined the daily mean, standard deviation(STD) and median values for energy, macro- and micronutrient intake for the 1991 and 1995 groups.

4.2.2.1 Derivation of nutrient categories and dmfs score group variables

Inter-individual dietary intake and caries scores can vary quite substantially which makes the group mean intake relatively unreliable. A frequency distribution of dmfs scores and each nutrient intake for the group in ascending or descending order enables the values to be divided into quartiles or thirds (272). This method is less subject to the disadvantages of using the range. With the BTT study having a large number of observations and the advantages of this measure of variation, energy and each nutrient variable were divided into quartiles and thirds (ranges are shown in Tables 2.4 and 2.5) and dmfs scores were categorised into three category groupings (classifications): dk (=0 or >0); dk2(=0, 1-4, ≥5) and dk3(=0, 1-4, 5-9, ≥10). Classification 1 was dk which had 2 dmfs score groups, classification 2 - dk2 with 3 score groups and classification 3 - dk3 with 4 score groups.

Table 4.3 Ranges of quartiles of energy, macro- and micronutrients

	Quartiles			
	1	2	3	4
	<	≥ - <	≥ - <	≥
energy (kcal)	1729	1729-2034	2034-2387	2387
protein (g)	47	47-55	55-65	65
fat (g)	73	73-89	89-112	112
cholesterol (g)	214	214-296	296-372	372
total available carbohydrate (g)	214	214-254	254-296	296
fibre (g)	13	13-17	17-20	20
added sugar (g)	55	55-71	71-94	94
calcium (mg)	456	456-612	612-796	796
vitamin B12 (μg)	1.9	1.9-2.5	2.5-3.1	3.1
iron (mg)	6.1	6.1-7.3	7.3-8.6	8.6
magnesium (mg)	228	228-273	273-318	318
phosphorus (mg)	842	842-1012	1012-1216	1216
potassium (mg)	1774	1774-2125	2125-2468	2468
sodium (mg)	1499	1499-1863	1863-2281	2281
zinc (mg)	6.1	6.1-7.1	7.1-8.4	8.4
copper (mg)	0.7	0.7-0.8	0.8-1.0	1.0
vitamin A (RE)	393	393-530	530-680	680
thiamin (mg)	0.8	0.8-1.0	1.0-1.2	1.2
riboflavin (mg)	0.8	0.8-1.1	1.1-1.4	1.4
nicotinic acid (mg)	9.0	9.0-10.9	10.9-12.9	12.9
vitamin B6 (mg)	1.1	1.1-1.4	1.4-1.7	1.7
folic acid (μg)	138	138-172	172-217	217
ascorbic acid (mg)	28	28-37	37-49	49
pantothenic acid (mg)	2.7	2.7-3.3	3.3-3.9	3.9
biotin (μg)	16	16-20	20-25	25
vitamin D (μg)	1.5	1.5-2.7	2.7-4.2	4.2
vitamin E (mg)	9.6	9.6-15.0	15.0-20.9	20.9
manganese (mg)	1.9	1.9-2.6	2.6-3.2	3.2

Table 4.4 Ranges of thirds of energy, macro- and micronutrients

	Thirds		
	1	2	3
	<	≥ - <	≥
energy (kcal)	1830	1830-2266	2266
protein (g)	50	20-60	60
fat (g)	78	78-103	103
cholesterol (g)	245	245-351	351
total available carbohydrate (g)	228	228-279	279
fibre (g)	15	15-19	19
added sugar (g)	59	59-86	86
calcium (mg)	509	509-738	738
vitamin B12 (μg)	2.1	2.1-2.9	2.9
iron (mg)	6.5	6.5-8.1	8.1
magnesium (mg)	242	242-300	300
phosphorus (mg)	908	908-1145	1145
potassium (mg)	1905	1905-2342	2342
sodium (mg)	1632	1632-2101	2101
zinc (mg)	6.5	6.5-7.9	7.9
copper (mg)	0.7	0.7-1.0	1.0
vitamin A (RE)	441	441-623	623
thiamin (mg)	0.8	0.8-1.1	1.1
riboflavin (mg)	0.9	0.9-1.3	1.3
nicotinic acid (mg)	9.7	9.7-12.3	12.3
vitamin B6 (mg)	1.2	1.2-1.6	1.6
folic acid (μg)	151	151-200	200
ascorbic acid (mg)	30	30-43	43
pantothenic acid (mg)	2.9	2.9-3.7	3.7
biotin (μg)	17	17-23	23
vitamin D (μg)	2.0	2.0-4.1	4.1
vitamin E (mg)	11.3	11.3-18.9	18.9
manganese (mg)	2.1	2.1-2.9	2.9

4.2.2.2 Derivation of a social class variable

A social class variable was derived from the occupation of the father (mother if the father was unemployed or no longer in the family) using the six British social classes (273) and South African occupation descriptions (274), successfully used in other investigations (41). These six classes are :

I. Independent and high professional

II. Salaried professional and equivalent

IIIN. Owners and executives in small commerce and services

IIIM. Working owner in small commerce/service.

IV. Routine non-manual

V. Unskilled manual.

The six classes were then condensed into upper (I, II, IIIN) and lower (IIIM, IV, V). The occupational classification was based on the usual occupation of a parent irrespective of whether the parent was employed or not at the time of the survey.

In South Africa seven years of primary school are followed by five years of secondary school, culminating in matriculation (high school diploma). Tertiary education can be at a university, technical college or commercial college. Three family education groups were defined according to combinations of the years of schooling completed by the parents (41). In the low group both parents had completed less than 10 years of schooling. The middle group contained one parent who had completed 10-12 years of schooling and the other 7-12 years. The high group had one parent with 12 years of completed schooling plus tertiary education, the other with at least 10-12 years of schooling. In single parent households the

education level of that parent was used.

4.2.3 Statistical analysis procedures to study the relationship between energy, macro- and micronutrient intake and dental caries among 5-year-old children

Several statistical tests were done using SAS (157).

4.2.3.1 Kruskal-Wallis test (Proc NPAR1WAY)

The study's diet credibility was tested to determine if the longitudinal sample investigated was representative of all urban black South African preschool children in the Birth-to-Ten study.

4.2.3.2 The Mantel-Haenszel x^2 test (Proc Freq)

The Mantel-Haenszel x^2 test for trend was carried out on each nutrient in quartiles and thirds for each dmfs category (3 classifications of dmfs scores - see 4.2.2.1). This was done for the whole sample of urban black 5-year-olds [n=1096] who had nutrition **and/or** dental information for 1995, as well as for the true longitudinal cohort [n=300] who had nutrition information for 1991 **and** 1995 **as well** as dental information for 1995.

4.2.3.3 Linear logistic (Proc Catmod)

Caries groupings (3 classifications of dmfs scores - see 4.2.2.1) were evaluated as dependent variables with a Proc Catmod (linear logistic analysis) for caries prevalence. The independent variables in the analysis were quartiles for energy, macro- and micronutrients and the confounding variables of social class and parents education level. For all multivariate

analyses the independent variables; social class, education level and each nutrient, were entered simultaneously. The critical level for statistical significance was set at $p<0.05$.

4.2.3.4 General linear models (Proc GLM) and logistic regression (Proc Reg)

For the analysis of discrete caries data (prevalence) a logistic regression analysis was used. The distribution of the dmfs scores (caries severity) was highly skewed. Transformation to exact normality of such ordinal data is not possible. However, it is possible to achieve a key feature of normality - namely, zero skewness by a systematic search among the family of transformations: log(dmfs+k). Repeated systematic searches through the data showed that the k achieving zero skewness for the whole group was 0.275 and for the longitudinal cohort it was 0.3. In these families of so called Box-Cox transformations with shift the selection is restricted to small subfamilies and is done by eye (275). This is a very particular case of the Box-Cox transformations with shift.

The log(dmfs + 0.275) and log(dmfs + 0.3), as dependent variables, were evaluated with a general linear model (Proc GLM). Nutrient variables, social class and parents education level were the independent variables in the analysis.

Presence (dmfs>0) or absence of caries was also evaluated using a linear logistic regression analysis including energy and nutrient variables as independent variables. Presence or absence of caries was the dependent variable for the whole group (n=423) and for the longitudinal group (n=300). Logistic regression analysis was carried out on dmfs and on the transformation of log(dmfs+k) for those children with caries only (dmfs>0) in the whole

group (n=260) and in the longitudinal group (n=184). Energy, macro- and micronutrients and confounding variables of social class and parents education level were included as independent variables with presence of caries as the dependent variable. The critical level of statistical significance was set at $P<0.05$.

Many of the dmfs scores were zero which suggested that multiple regression analysis, even on the transformation of log(dmfs) was not appropriate. Also, hunting for mildly significant effects in a large number of analyses as above was not scientifically justified. With rationale behind the selection of the family of transformations log(dmfs+k) the results of these regression analyses were selected to be reported in this thesis in chapter 4.0. The results of the other analyses are available.

The above analyses, however, still do not overcome the hunting for mildly significant effects.

4.3 Results

4.3.1 Diet credibility testing results

The study's diet credibility was tested to determine if the sample used was nutritionally representative of urban black South African preschool children in the Birth-to Ten study. The Kruskal-Wallis test showed that urban black South African children that had nutrition information for 1991 and 1995 **and/or** dental information for 1995 n=763 (longitudinal cohort) were nutritionally representative of the groups that only had nutrition information at 1991 n=949 and 1995 n=333 (cross sectional cohorts). Only vitamin D showed a

significantly greater difference at 1991 ($P< 0.032$) and ascorbic acid at 1995 ($P<0.0001$) (Tables 4.5 and 4.6). The P value for vitamin D could be a chance effect, given that so many tests have been performed, but the highly significant difference in ascorbic acid cannot be explained away so lightly. This remains as an unanswered questioned..

In Tables 4.5-4.8 two to four digit values for the 95% confidence intervals have been rounded to full integers except for where the difference between the upper and lower level was small and for single values where results are shown to two decimal places.

Table 4.5 Kruskal-Wallis Test P values between 5-year-old urban black South African children that had nutrition information for 1991 and 1995 and/or dental information for 1995 (1991/95 longitudinal) and those that only had nutrition information for 1991 (1991 cross-sectional)

	1991 cross-sectional n=949			1991/95 longitudinal at 1991 n=763			
Variable	mean	95% CI	median	mean	95% CI	median	P value
energy (kcal)	826	816-846	697	774	746-801	696	0.421
protein (g)	33	32-34	29	31	30-32	29	0.636
fat (g)	36	34-38	30	33	32-34	30	0.313
total available carbohydrate (g)	91	88-94	79	87	84-90	77	0.509
fibre (g)	5.2	5.05-5.35	4.9	5.3	5.12-5.48	5.0	0.723
added sugar (g)	17	16-18	14	17	16-18	14	0.552
calcium (g)	474	445-503	431	429	406-452	436	0.998
vitamin B12 (μg)	2.8	2.70-2.90	2.5	2.7	2.61-2.79	2.5	0.598
iron (mg)	5.7	5.27-6.13	3.8	4.8	4.47-5.13	4.6	0.247
magnesium (mg)	112	109-115	104	111	108-114	104	0.945
phosphorus (mg)	583	559-607	534	557	537-577	533	0.922
potassium (mg)	1134	1092-1176	1013	1085	1046-1124	1003	0.633
sodium (mg)	696	672-720	611	682	658-706	611	0.700
zinc (mg)	4.6	4.40-4.80	3.8	4.4	4.22-4.58	3.8	0.633
copper (mg)	0.4	0.38-0.42	0.4	0.4	0.39-0.41	0.3	0.088
vitamin A (RE)	392	367-417	369	344	322-366	270	0.341
thiamin (mg)	0.5	0.47-0.53	0.4	0.5	0.48-0.52	0.4	0.314
riboflavin (mg)	0.9	0.86-0.94	0.8	0.9	0.86-0.94	0.8	0.499
nicotinic acid (mg)	5.6	5.35-5.85	4.4	5.2	4.95-5.45	4.2	0.172
vitamin B6 (mg)	0.7	0.67-0.73	0.6	0.7	0.67-0.73	0.6	0.171
folic acid (μg)	96	93-99	84	92	89-95	81	0.132
ascorbic acid (mg)	46	43-49	32	41	38-44	33	0.172
pantothenic acid (mg)	2.5	2.39-2.61	2.2	2.3	2.20-2.40	2.2	0.160
biotin (μg)	18	17-19	16	17	16-18	16	0.195
vitamin D (μg)	5.4	5.02-5.78	4.2	4.4	4.07-4.73	4.2	0.032*
vitamin E (mg)	6.1	5.81-6.39	5.1	5.5	5.23-5.77	4.9	0.070

* = statistically significant (P<0.05)

Table 4.6 Kruskal-Wallis Test P values between 5-year-old urban black South African children that had nutrition information for 1991 and 1995 and/or dental information for 1995 (1991/95 longitudinal) and those that only had nutrition information for 1995 (1995 cross-sectional)

	1995 cross-sectional n=333			1991/95 longitudinal at 1995 n=763			
Variable	mean	95% CI	median	mean	95% CI	median	P value
energy (kcal)	2091	2028-2154	2057	2097	2060-2134	2031	0.853
protein (g)	56	54-58	55	57	57-58	55	0.950
fat (g)	93	89-97	90	96	93-99	90	0.488
total available carbohydrate (g)	263	254-271	256	257	253-261	254	0.376
fibre (g)	17	16-18	17	18	17-18	17	0.063
added sugar (g)	78	73-83	73	76	74-78	71	0.495
calcium (mg)	658	623-693	626	648	622-674	605	0.371
vitamin B12 (μg)	2.6	2.49-2.71	2.6	2.6	2.51-2.69	2.6	0.785
iron (mg)	7.5	7.27-7.73	7.3	7.5	7.36-7.64	7.3	0.909
magnesium (mg)	272	264-280	266	277	272-282	275	0.214
phosphorus (mg)	1042	1005-1080	1017	1051	1025-1078	1009	0.938
potassium (mg)	2160	2094-2226	2163	2147	2101-2193	2105	0.438
sodium (mg)	1926	1860-1992	1873	1921	1873-1969	1861	0.693
zinc (mg)	7.3	7.08-7.52	7.1	7.3	7.17-7.43	7.2	0.869
copper (mg)	0.9	0.87-0.93	0.9	0.9	0.89-0.91	0.9	0.688
vitamin A (RE)	550	527-573	515	555	539-571	538	0.591
thiamin (mg)	1.0	0.97-1.03	1.0	1.0	0.97-1.03	1.0	0.381
riboflavin (mg)	1.2	1.15-1.25	1.1	1.2	1.16-1.24	1.1	0.439
nicotinic acid (mg)	11.1	10.8-11.4	10.9	11.4	11.1-11.7	11.0	0.524
vitamin B6 (mg)	1.4	1.35-1.45	1.4	1.4	1.36-1.44	1.4	0.503
folic acid (μg)	185	178-192	174	189	180-198	172	0.878
ascorbic acid (mg)	56	52-60	40	47	44-50	36	0.0001*
pantothenic acid (mg)	3.4	3.28-3.52	3.3	3.4	3.32-3.48	3.4	0.680
biotin (μg)	21	20-22	20	21	20-22	21	0.275
vitamin D (μg)	3.0	2.56-3.44	2.6	2.9	2.74-3.06	2.8	0.633
vitamin E (mg)	17.1	15.8-18.4	15.8	18.6	17.4-19.8	14.9	0.806

* = statistically significant (P<0.05)

Those children that had nutrition information for 1991 and 1995 and dental information for 1995 n=300 (longitudinal cohort) were significantly different at 1991 for several nutrients from those that only had nutrition information for 1991 and 1995 n=463 (1991/1995 cross-sectional cohort). By 1995, however, when caries had developed, this true longitudinal cohort (n=300) were nutritionally representative of the cross-sectional group with only vitamin A being marginally significantly different ($P<0.0426$) (Tables 4.7 and 4.8).

Table 4.7 Kruskal-Wallis Test P values between 5-year old urban black South African children that had nutrition information for 1991 and 1995 and dental information for 1995 (1991/95 longitudinal) and those that only had nutrition information for 1991 (1991 cross-sectional)

	1991 cross-sectional n=463			1991/95 longitudinal at 1991 n=300			
Variable	mean	95% CI	median	mean	95% CI	median	P value
energy (kcal)	786	753-819	723	757	709-805	652	0.006*
protein (g)	32	31-33	30	31	29-33	27	0.003*
fat (g)	34	32-36	31	32	30-34	28	0.003*
total available carbohydrate (g)	87	88-91	81	87	81-93	73	0.040*
fibre (g)	5.4	5.19-5.61	5.1	5.3	4.98-5.62	4.6	0 169
added sugar (g)	17	16-18	15	16	14-18	13	0.063
calcium (mg)	435	409-461	447	418	377-459	425	0.016*
vitamin B12 (μg)	2.8	2.68-2.92	2.6	2.6	2.45-2.75	2.3	0.008*
iron (mg)	4.7	4.32-5.08	3.8	4.9	4.29-5.51	3.4	0.069
magnesium (mg)	112	108-116	107	110	104-116	98	0.032*
phosphorus (mg)	566	543-590	559	544	507-581	506	0.006*
potassium (mg)	1098	1052-1144	1039	1066	996-1136	958	0.032*
sodium (mg)	696	665-727	634	661	622-700	575	0.027*
zinc (mg)	4.4	4.20-4.60	3.9	4.2	3.88-4.52	3.5	0.003*
copper (mg)	0.4	0.38-0.42	0.4	0.4	0.37-0.43	0.3	0.042*
vitamin A (RE)	343	317-370	275	344	307-381	257	0.135
thiamin (mg)	0.5	0.47-0.53	0.4	0.5	0.47-0.53	0.4	0.082
riboflavin (mg)	0.9	0.85-0.95	0.8	0.8	0.74-0.86	0.7	0.014*
nicotinic acid (mg)	5.3	4.99-5.61	4.3	5.2	4.78-5.62	4.1	0.042*
vitamin B6 (mg)	0.7	0.66-0.74	0.6	0.7	0.65-0.75	0.5	0.044*
folic acid (μg)	93	89-97	84	91	85-97	79	0.062
ascorbic acid (mg)	41	38-44	34	41	37-45	30	0.084
pantothenic acid (mg)	2.4	2.28-2.52	2.2	2.3	2.13-2.47	2.0	0.015*
biotin (μg)	17	16-18	16	16	15-17	15	0.143
vitamin D (μg)	4.4	4.01-4.79	4.2	4.6	4.03-5.17	4.2	0.456
vitamin E (mg)	5.6	5.26-5.94	5.0	5.5	5.07-5.93	4.9	0.127

* = statistically significant ($P<0.05$)

Table 4.8 Kruskal-Wallis Test P values between 5-year-old urban black South African children that had nutrition information for 1991 and 1995 and dental information for 1995 (1991/95 longitudinal) and those that only had nutrition information for 1995 (1995 cross-sectional)

	1995 cross-sectional n=463			1991/95 longitudinal at 1995 n=300			
Variable	mean	95% CI	median	mean	95% CI	median	P value
energy (kcal)	2116	2067-2165	2058	2066	2007-2122	1998	0.277
protein (g)	57	56-58	56	56	55-57	55	0.362
fat (g)	98	95-101	91	93	89-97	88	0.088
total available carbohydrate (g)	258	253-263	254	257	250-264	252	0.837
fibre (g)	18	18-19	17	18	17-19	18	0.050
added sugar (g)	75	72-78	72	76	72-80	70	0.723
calcium (mg)	661	623-699	613	626	595-657	597	0.330
vitamin B12 (μg)	2.7	2.57-2.83	2.6	2.5	2.40-2.60	2.5	0.069
iron (mg)	7.6	7.42-7.78	7.4	7.4	7.20-7.60	7.3	0.316
magnesium (mg)	278	271-285	275	276	268-284	275	0.991
phosphorus (mg)	1061	1024-1098	1017	1035	999-1071	999	0.440
potassium (mg)	2175	2110-2240	2114	2103	2040-2166	2100	0.301
sodium (mg)	1927	1862-1992	1879	1911	1841-1982	1835	0.864
zinc (mg)	7.3	7.12-7.48	7.2	7.2	7.01-7.39	7.2	0.747
copper (mg)	0.9	0.88-0.92	0.9	0.9	0.88-0.92	0.9	0.902
vitamin A (RE)	568	547-589	551	535	511-559	520	0.043*
thiamin (mg)	1.1	1.06-1.14	1.0	1.0	0.97-1.03	1.0	0.384
riboflavin (mg)	1.2	1.14-1.26	1.1	1.1	1.04-1.16	1.1	0.101
nicotinic acid (mg)	11.4	11.0-11.8	11.0	11.2	10.8-11.6	11.0	0.465
vitamin B6 (mg)	1.5	1.45-1.55	1.4	1.4	1.35-1.45	1.4	0.052
folic acid (μg)	189	177-201	173	188	175-201	171	0.634
ascorbic acid (mg)	47	44-50	36	48	44-52	36	0.616
pantothenic acid (mg)	3.5	3.39-3.61	3.4	3.4	3.30-3.50	3.3	0.163
biotin (μg)	21	21-22	21	21	21-22	21	0.258
vitamin D (μg)	2.9	2.76-3.04	3.0	3.0	2.67-3.33	2.7	0.249
vitamin E (mg)	19.2	17.7-20.7	15.1	17.8	16.0-19.6	14.6	0.341

* = statistically significant ($P<0.05$)

4.3.2 Energy, macro- and micronutrient intake in relation to the prevalence dental caries - Mantel Haenszel x^2 test results

In the following sections 4.3.2 and 4.3.3 incidence and prevalence of dental caries will be discussed. To clarify these two definitions for this study incidence indicates caries experience between the first and the last investigation in the longitudinal group. Since the longitudinal group virtually had no caries at 1-year the dmfs value at 5-years approximates true incidence. For the cross-sectional group the dmfs value at each time interval is prevalence. Prevalence is indicated by the number of cases at a particular time and refers to the percentage of individuals with caries.

Several statistical tests were carried out to determine if any macro-, and particularly micronutrients, could be predictors of the incidence or prevalence of dental caries among all 5-year-old urban black children (n=1096) as well as among only the true longitudinal group (n=300). As the thesis is directed towards the diet as a whole and concentrates specifically on micronutrients, macro- and micronutrients have been separated in the tables in the results and will be discussed separately for each statistical test.

The nutrients (28 variables) were subsequently divided into both quartiles and thirds for all the children [n=1096] as well as for the longitudinal group [n=300] and caries scores classified into three category groupings (classifications). These classifications are explained fully in the methods section 4.2.2.1. Only the quartile results and the statistical analyses of these will be shown in the results section of this chapter. The detailed results and statistical analysis for the thirds are included in Appendix H (Tables H1-H4), but the main findings

will be mentioned briefly in 4.3.2.3. The reason for using both types of grouping is that there is no general agreement in the literature on what grouping is best. Both were done for completeness.

4.3.2.1 Quartiles for energy and macronutrients

The Mantel-Haenszel x^2 test for trend for macronutrients divided into quartiles (Table 4.9) showed only energy to be almost associated with caries prevalence ($P<0.055$) when caries was classified into 2 score groups (classification 1) for all the children. However, when caries scores were classified into 3 (classification 2) and 4 (classification 3) groups fat, fibre and added sugar, in addition to energy, were associated with caries prevalence.

Only energy was associated with caries prevalence among the longitudinal group (Table 4.10).

4.3.2.2 Quartiles for micronutrients

For all the 5-year-olds among the micronutrients (Table 4.11) calcium, vitamins B12 and A and riboflavin showed an association with caries prevalence for 3 (classification 2) and 4 (classification 3) dmfs score groups only, riboflavin being highly associated ($P<0.005$). Only calcium showed an association among the longitudinal group (Table 4.12).

4.3.2.3 Thirds for macro- and micronutrients

Fat, cholesterol, and added sugar (macronutrients) and calcium, riboflavin and vitamins B12 and E (micronutrients) were associated with caries prevalence for the whole group.

Only calcium, rib-flavin and vitamin E were associated for the longitudinal group.

Table 4.9 Mantel-Haenszel x^2 test for trend for caries groups (quartiles)

I. Macronutrients for whole group n=423 (df=1 for all nutrients)

Nutrient	classification 1		classification 2		classification 3	
	x^2	P	x^2	P	x^2	P
energy	3.67	0.055*	5.02	0.025*	7.49	0.006*
protein	0.31	0.580	1.00	0.317	1.19	0.275
fat	2.14	0.144	3.90	0.048*	4.57	0.033*
cholesterol	0.53	0.469	2.27	0.132	3.28	0.070
total available carbohydrate	1.19	0.275	2.27	0.132	2.61	0.106
fibre	2.78	0.095	3.72	0.054*	4.45	0.035*
added sugar	2.32	0.127	5.63	0.018*	6.51	0.011*

* = statistically significant ($P<0.05$)

classification 1 = dmfs scores <0 or >0

classification 2 = dmfs scores 0, 1-4, ≥5

classification 3 = dmfs scores 0, 1-4, 5-9, ≥10

Table 4.10 Mantel-Haenszel x^2 test for trend for caries groups (quartiles)

I. Macronutrients for longitudinal group n=300 (df=1 for all nutrients)

Nutrient	classification 1		classification 2		classification 3	
	x^2	P	x^2	P	x^2	P
energy	1.89	0.169	3.43	0.064	4.68	0.030*
protein	0.17	0.679	1.05	0.306	1.02	0.312
fat	0.30	0.583	0.97	0.324	1.14	0.285
cholesterol	0.07	0.791	0.55	0.460	0.93	0.336
total available carbohydrate	0.80	0.370	1.23	0.267	0.98	0.321
fibre	0.27	0.607	0.32	0.567	0.55	0.460
added sugar	0.84	0.358	1.99	0.159	1.91	0.167

* = statistically significant ($P<0.05$)

classification 1 = dmfs scores <0 or >0

classification 2 = dmfs scores 0, 1-4, ≥5

classification 3 = dmfs scores 0, 1-4, 5-9, ≥10

Table 4.11 Mantel-Haenszel x^2 test for trend for caries groups (quartiles)

II. Micronutrients for whole group n=423 (df=1 for all nutrients)

Nutrient	classification 1		classification 2		classification 3	
	x^2	P	x^2	P	x^2	P
calcium	2.83	0.092	5.74	0.017*	5.64	0.018*
vitamin B12	0.97	0.325	4.12	0.042*	4.87	0.027*
iron	0.01	0.912	0.16	0.690	0.35	0.556
magnesium	0.00	0.978	0.14	0.713	0.56	0.454
phosphorus	0.43	0.511	1.88	0.170	1.66	0.198
potassium	1.56	0.212	2.91	0.088	3.16	0.075
sodium	0.04	0.845	0.24	0.622	0.38	0.540
zinc	0.41	0.521	1.00	0.318	0.94	0.333
copper	0.85	0.357	1.13	0.288	1.32	0.251
vitamin A (RE)	1.50	0.221	4.03	0.045*	5.50	0.019*
thiamin	0.75	0.386	1.94	0.163	2.38	0.123
riboflavin	1.50	0.220	6.21	0.013*	7.81	0.005*
nicotinic acid	0.00	0.995	0.02	0.884	0.02	0.901
vitamin B6	0.55	0.458	0.36	0.549	0.24	0.628
folic acid	0.02	0.878	0.28	0.598	0.44	0.505
ascorbic acid	0.31	0.576	1.07	0.300	1.94	0.164
pantothenic acid	1.34	0.247	2.63	0.105	3.14	0.077
biotin	0.04	0.852	1.23	0.267	1.49	0.222
vitamin D	0.49	0.485	2.08	0.149	2.73	0.099
vitamin E	0.04	0.841	0.34	0.560	1.30	0.254
manganese	1.74	0.188	1.20	0.273	2.01	0.157

* = statistically significant ($P<0.05$)

classification 1 = dmfs scores <0 or >0

classification 2 = dmfs scores 0, 1-4, $\geq$5

classification 3 = dmfs scores 0, 1-4, 5-9, $\geq$10

Table 4.12 Mantel-Haenszel x^2 test for trend for caries groups (quartiles)

II. Micronutrients for longitudinal group n=300 (df=1 for all nutrients)

Nutrient	classification 1		classification 2		classification 3	
	x^2	P	x^2	P	x^2	P
calcium	1.62	0.203	4.58	0.032*	4.33	0.037*
vitamin B12	0.00	0.997	1.75	0.186	1.80	0.180
iron	0.05	0.833	0.81	0.368	1.10	0.294
magnesium	0.61	0.435	0.42	0.519	0.10	0.757
phosphorus	0.26	0.608	1.89	0.169	1.68	0.195
potassium	0.57	0.451	1.51	0.219	1.54	0.215
sodium	0.17	0.679	0.13	0.717	0.16	0.685
zinc	0.33	0.565	1.31	0.258	1.02	0.313
copper	0.44	0.507	0.67	0.414	0.71	0.400
vitamin A (RE)	0.17	0.684	0.94	0.333	1.24	0.265
thiamin	0.19	0.660	1.30	0.254	1.31	0.253
riboflavin	0.09	0.769	2.77	0.096	3.43	0.064
nicotinic acid	0.22	0.641	0.31	0.580	0.20	0.651
vitamin B6	0.02	0.879	0.02	0.886	0.01	0.909
folic acid	0.03	0.374	0.55	0.459	0.66	0.417
ascorbic acid	0.00	0.972	0.37	0.544	0.90	0.344
pantothenic acid	0.09	0.764	0.72	0.398	0.74	0.389
biotin	0.31	0.579	0.28	0.595	0.25	0.616
vitamin D	0.38	0.535	0.21	0.645	0.30	0.583
vitamin E	0.03	0.865	0.28	0.594	0.86	0.353
manganese	0.22	0.637	0.00	0.998	0.02	0.879

* = statistically significant ($P<0.05$)

classification 1 = dmfs scores <0 or >0

classification 2 = dmfs scores 0, 1-4, ≥5

classification 3 = dmfs scores 0, 1-4, 5-9, ≥10

Table 4.12 Mantel-Haenszel x^2 test for trend for caries groups (quartiles)

II. Micronutrients for longitudinal group n=300 (df=1 for all nutrients)

Nutrient	classification 1		classification 2		classification 3	
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calcium	1.62	0.203	4.58	0.032*	4.33	0.037*
vitamin B12	0.00	0.997	1.75	0.186	1.80	0.180
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magnesium	0.61	0.435	0.42	0.519	0.10	0.757
phosphorus	0.26	0.608	1.89	0.169	1.68	0.195
potassium	0.57	0.451	1.51	0.219	1.54	0.215
sodium	0.17	0.679	0.13	0.717	0.16	0.685
zinc	0.33	0.565	1.31	0.258	1.02	0.313
copper	0.44	0.507	0.67	0.414	0.71	0.400
vitamin A (RE)	0.17	0.684	0.94	0.333	1.24	0.265
thiamin	0.19	0.660	1.30	0.254	1.31	0.253
riboflavin	0.09	0.769	2.77	0.096	3.43	0.064
nicotinic acid	0.22	0.641	0.31	0.580	0.20	0.651
vitamin B6	0.02	0.879	0.02	0.886	0.01	0.909
folic acid	0.03	0.374	0.55	0.459	0.66	0.417
ascorbic acid	0.00	0.972	0.37	0.544	0.90	0.344
pantothenic acid	0.09	0.764	0.72	0.398	0.74	0.389
biotin	0.31	0.579	0.28	0.595	0.25	0.616
vitamin D	0.38	0.535	0.21	0.645	0.30	0.583
vitamin E	0.03	0.865	0.28	0.594	0.86	0.353
manganese	0.22	0.637	0.00	0.998	0.02	0.879

* = statistically significant ($P<0.05$)

classification 1 = dmfs scores <0 or >0

classification 2 = dmfs scores 0, 1-4, ≥5

classification 3 = dmfs scores 0, 1-4, 5-9, ≥10

4.3.2.4 Frequency distribution for associated macro- and micronutrients (quartiles)

Tables 4.13-4.32 show the frequency distributions of caries score groups by quartiles of only the associated macro- and micronutrients mentioned previously. When the total added up to just under or above 100% this was due to rounding of decimals. The frequency distribution aids interpretation of clinical relevance. Similarly the frequency distribution of caries scores by thirds are included in Appendix I as Tables I.1-I.17.

Table 4.13 Frequency distribution of two dmfs score groups by quartiles of energy
Whole group n=423

	Quartiles				
dmfs score	1	2	3	4	total
	<1729	≥1729<2034	≥2034<2387	≥2387	
<0 n (%)	45 (28)	46 (28)	44 (27)	28 (17)	163 (100)
>0 n (%)	63 (24)	66 (25)	59 (23)	72 (28)	260 (100)
Total	108	112	103	100	

Table 4.14 Frequency distribution of three dmfs score groups by quartiles of energy

Whole group n=423

	Quartiles				
dmfs score	1	2	3	4	total
	<1729	≥1729<2034	≥2034<2387	≥2387	
0 n (%)	45 (28)	46 (28)	44 (27)	28 (17)	163 (100)
1-4 n (%)	32 (26)	34 (28)	25 (21)	30 (25)	121 (100)
≥5 n (%)	31 (22)	32 (23)	34 (24)	42 (31)	139 (100)
total	108	112	103	100	

Table 4.15 Frequency distribution of three dmfs score groups by quartiles of fat

Whole group n=423

	Quartiles				
dmfs score	1	2	3	4	total
	<73	≥73<89	≥89<112	≥112	
0 n (%)	37 (23)	53 (33)	45 (28)	28 (17)	163 (101)
1-4 n (%)	35 (29)	27 (22)	29 (24)	30 (25)	121 (100)
≥5 n (%)	32 (23)	27 (19)	38 (27)	42 (30)	139 (99)
total	104	107	112	100	

Table 4.16 Frequency distribution of three dmfs score groups by quartiles of fibre

Whole group n=423

	Quartiles				
dmfs score	1	2	3	4	total
	<13	≥13<17	≥17<20	≥20	
0 n (%)	27 (17)	47 (29)	34 (21)	55 (34)	163 (101)
1-4 n (%)	29 (24)	29 (24)	24 (20)	39 (32)	121 (100)
≥5 n (%)	31 (24)	46 (33)	28 (20)	34 (24)	139 (101)
total	87	122	86	128	

Table 4.17 Frequency distribution of three dmfs score groups by quartiles of added sugar

Whole group n=423

	Quartiles				
dmfs score	1	2	3	4	total
	<55	≥55<71	≥71<94	≥94	
0 n (%)	36 (22)	57 (35)	35 (21)	35 (21)	163 (99)
1-4 n (%)	30 (25)	34 (28)	32 (26)	25 (21)	121 (100)
≥5 n (%)	24 (17)	35 (25)	35 (25)	45 (32)	139 (99)
total	90	126	102	105	

Table 4.18 Frequency distribution of three dmfs score groups by quartiles of calcium

Whole group n=423

	Quartiles				
dmfs score	1	2	3	4	total
	<456	≥456<612	≥612<796	≥796	
0 n (%)	49 (30)	40 (25)	40 (25)	34 (21)	163 (101)
1-4 n (%)	35 (29)	28 (23)	32 (26)	26 (21)	121 (99)
≥5 n (%)	24 (17)	40 (29)	32 (23)	43 (31)	139 (100)
total	108	108	104	103	

Table 4.19 Frequency distribution of three dmfs score groups by quartiles of vitamin B12

Whole group n=423

	Quartiles				
dmfs score	1	2	3	4	total
	<1.9	≥1.9<2.5	≥2.5<3.1	≥3.1	
0 n (%)	46 (28)	38 (23)	43 (26)	36 (22)	163 (99)
1-4 n (%)	38 (31)	30 (25)	26 (21)	27 (22)	121 (99)
≥5 n (%)	28 (20)	28 (20)	41 (30)	42 (30)	139 (100)
total	112	96	110	105	

Table 4.20 Frequency distribution of three dmfs score groups by quartiles of riboflavin

Whole group n=423

	Quartiles				
dmfs score	1	2	3	4	total
	<0.8	≥0.8<1.1	≥1.1<1.4	≥1.4	
0 n (%)	42 (26)	42 (26)	40 (25)	39 (24)	163 (101)
1-4 n (%)	30 (25)	37 (31)	32 (26)	22 (18)	121 (100)
≥5 n (%)	19 (14)	38 (27)	35 (25)	47 (34)	139 (100)
tot al	91	117	107	108	

Table 4.21 Frequency distribution of three dmfs score groups by quartiles of vitamin A (RE)

Whole group n=423

	Quartiles				
dmfs score	1	2	3	4	total
	<393	≥393<530	≥530<680	≥680	
0 n (%)	50 (31)	41 (25)	37 (23)	35 (21)	163 (100)
1-4 n (%)	36 (30)	31 (26)	31 (26)	23 (19)	121 (101)
≥5 n (%)	26 (19)	37 (27)	41 (30)	35 (25)	139 (101)
total	112	10	109	93	

Table 4.22 Frequency distribution of three dmfs score groups by quartiles of calcium

longitudinal group n=300

	Quartiles				
dmfs score	1	2	3	4	total
	<456	≥456<612	≥612<796	≥796	
0 n (%)	34 (29)	31 (27)	27 (23)	24 (21)	116 (100)
1-4 n (%)	27 (30)	24 (27)	19 (21)	19 (21)	89 (99)
≥5 n (%)	15 (16)	29 (31)	21 (22)	30 (32)	95 (101)
total	76	84	67	73	

Table 4.23 Frequency distribution of four dmfs score groups by quartiles of energy

Whole group n=423

	Quartiles				
dmfs score	1	2	3	4	total
	<1729	≥1729<2034	≥2034<2387	≥2387	
0 n (%)	45 (28)	46 (28)	44 (27)	28 (17)	163 (100)
1-4 n (%)	32 (26)	34 (28)	25 (21)	30 (25)	121 (100)
5-9 n (%)	17 (21)	21 (26)	25 (31)	18 (22)	81 (100)
≥10 n (%)	14 (24)	11 (19)	9 (15)	24 (41)	58 (99)
total	108	112	103	100	

Table 4.24 Frequency distribution of four dmfs score groups by quartiles of fat

Whole group n=423

	Quartiles				
dmfs score	1	2	3	4	total
	<73	≥73<89	≥89<112	≥112	
0 n (%)	37 (23)	53 (33)	45 (28)	28 (17)	163 (101)
1-4 n (%)	35 (29)	27 (22)	29 (24)	30 (25)	121 (100)
5-9 n (%)	19 (23)	17 (21)	23 (28)	22 (27)	81 (99)
≥10 n (%)	13 (22)	10 (17)	15 (26)	20 (34)	58 (99)
total	104	107	112	100	

Table 4.25 Frequency distribution of four dmfs score groups by quartiles of fibre

whole group n=423

	Quartiles				
dmfs score	1	2	3	4	total
	<13	≥13<17	≥17<20	≥20	
0 n (%)	27 (17)	47 (29)	34 (21)	55 (34)	163 (101)
1-4 n (%)	29 (24)	29 (24)	24 (20)	39 (32)	121 (100)
5-9 n (%)	16 (20)	28 (35)	14 (17)	23 (18)	81 (100)
≥10 n (%)	15 (26)	18 (31)	14 (24)	11(19)	58 (100)
total	87	122	86	128	

Table 4.26 Frequency distribution of four dmfs score groups by quartiles of added sugar

Whole group n=423

	Quartiles				
dmfs score	1	2	3	4	total
	<55	≥55<71	≥71<94	≥94	
0 n (%)	26 (22)	57 (35)	35 (21)	35 (21)	163 (99)
1-4 n (%)	30 (25)	34 (28)	32 (26)	25 (21)	121 (100)
5-9 n (%)	11 (14)	26 (32)	22 (27)	22 (27)	81 (100)
≥10 n (%)	13 (22)	9 (16)	13 (22)	23 (40)	58 (100)
total	90	126	102	105	

Table 4.27 Frequency distribution of four dmfs score groups by quartiles of calcium

Whole group n=423

	Quartiles				
dmfs score	1	2	3	4	total
	<456	≥456<612	≥612<796	≥796	
0 n (%)	49 (30)	40 (25)	40 (25)	34 (21)	163 (101)
1-4 n (%)	35 (29)	28 (23)	32 (26)	26 (21)	121 (99)
5-9 n (%)	12 (15)	27 (33)	17 (21)	25 (31)	81 (100)
≥10 n (%)	12 (21)	13 (22)	15 (26)	18 (31)	58 (100)
total	108	108	104	103	

Table 4.28 Frequency distribution of four dmfs score groups by quartiles of vitamin B12

whole group n=423

	Quartiles				
dmfs score	1	2	3	4	total
	<1.9	≥1.9<2.5	≥2.5<3.1	≥3.1	
0 n (%)	46 (28)	38 (23)	43 (26)	36 (22)	163 (99)
1-4 n (%)	38 (31)	30 (25)	26 (21)	27 (22)	121 (99)
5-9 n (%)	18 (22)	15 (19)	24 (30)	24 (30)	81 (101)
≥10 n (%)	10 (17)	13 (22)	17 (29)	18 (31)	58 (99)
total	112	96	110	105	

Table 4.29 Frequency distribution of four dmfs score groups by quartiles of vitamin A (RE)
Whole group n=423

	Quartiles				
dmfs score	1	2	3	4	total
	<393	≥393<530	≥530<680	≥680	
0 n (%)	50 (31)	41 (25)	37 (23)	35 (21)	163 (100)
1-4 n (%)	36 (30)	31 (26)	31 (26)	23 (19)	121 (101)
5-9 n (%)	16 (20)	24 (30)	24 (30)	17 (21)	81 (101)
≥10 n (%)	10 (17)	13 (22)	17 (29)	18 (31)	58 (99)
total	112	109	109	93	

Table 4.30 Frequency distribution of four dmfs score groups by quartiles of riboflavin
Whole group n=423

	Quartiles				
dmfs score	1	2	3	4	total
	<0.8	≥0.8<1.1	≥1.1<1.4	≥1.4	
0 n (%)	42 (26)	42 (26)	40 (25)	39 (24)	163 (101)
1-4 n (%)	30 (25)	37 (31)	32 (26)	22 (18)	121 (100)
5-9 n (%)	10 (12)	28 (35)	17 (21)	26 (32)	81 (100)
≥10 n (%)	9 (16)	10 (17)	18 (31)	21 (36)	58 (100)
total	91	117	107	108	

Table 4.31 Frequency distribution of four dmfs score groups by quartiles of energy
longitudinal group n=300

	Quartiles				
dmfs score	1	2	3	4	total
	<1729	≥1729<2034	≥2034<2387	≥2387	
0 n (%)	31 (27)	36 (31)	28 (24)	21 (18)	116 (100)
1-4 n (%)	22 (25)	27 (30)	21 (24)	19 (21)	89 (100)
5-9 n (%)	13 (21)	15 (25)	19 (31)	14 (23)	61 (100)
≥10 n (%)	9 (26)	7 (21)	5 (15)	13 (38)	34 (100)
total	75	85	73	67	

Table 4.32 Frequency distribution of four dmfs score groups by quartiles of calcium longitudinal group n=300

	Quartiles				
dmfs score	1	2	3	4	total
	<456	≥456<612	≥612<796	≥796	
0 n (%)	34 (29)	31 (27)	27 (23)	24 (21)	116 (100)
1-4 n (%)	27 (30)	24 (27)	19 (21)	19 (21)	89 (99)
5-9 n (%)	8 (13)	21 (34)	12 (20)	20 (33)	61 (100)
≥10 n (%)	7 (21)	8 (24)	9 (26)	10 (29)	34 (100)
total	76	84	67	73	

4.3.3 Energy, macro- and micronutrient intake in relation to the prevalence of dental caries - Catmod (linear logistic) analysis results

Catmod analysis (linear logistic analysis) was done to relate the prevalence (presence or absence) of caries among the whole group of 5-year-old urban black children with nutrition and dental information for 1995 [n=423] as well as for the longitudinal group [n=300].

Catmod analysis determined if there was an association between the quartiles of nutrient intake, while the Mantel Haenszel x^2 test determined if there was an association in the order of these nutrients between the quartiles ie. it tested for trend.

With social class and education level of the parents excluded from the analysis (Table 4.33), energy was found to be associated with caries prevalence for the whole group with caries classified into 4 dmfs score groups (classification 3), and fat was associated for 2 and 3 dmfs score groups (classifications 1 and 2). Among the micronutrients (Table 4.34) magnesium, riboflavin, and biotin were associated with caries prevalence with caries classified into 3 and 4 dmfs score groups (classifications 2 and 3), while vitamin B6 related to caries prevalence with caries classified into 4 dmfs score groups (classification 3) only.

For the longitudinal group (Tables 4.35 and 4.36) only magnesium showed a weak association with caries prevalence with caries classified into 4 dmfs score groups. No other macro- or micronutrient showed any association.

Table 4.33 Catmod analysis of dmfs score groups by quartiles of macronutrients - whole group n=423

Nutrient	classification 1		classification 2		classification 3	
	x^2	P	x^2	P	x^2	P
energy	5.58	0.061	7.16	0.128	15.34	0.018*
protein	0.83	0.842	2.06	0.914	4.71	0.859
fat	10.47	0.015*	12.64	0.049*	13.60	0.137
cholesterol	0.54	0.910	5.80	0.446	8.45	0.489
total available carbohydrate	1.63	0.653	3.19	0.785	7.67	0.567
fibre	3.14	0.370	6.36	0.384	8.79	0.457
added sugar	4.41	0.220	9.85	0.131	16.03	0.066

* = statistically significant ($P<0.05$)

classification 1 = dmfs scores <0 or >0

classification 2 = dmfs scores 0,1-4, ≥5

classification 3 = dmfs scores 0,1-4,5-9,≥10

Table 4.34 Catmod analysis of dmfs score groups by quartiles of micronutrients - whole group n=423

Nutrient	classification 1		classification 2		classification 3	
	x^2	P	x^2	P	x^2	P
calcium	3.54	0.316	10.27	0.114	12.46	0.189
vitamin B12	1.16	0.762	8.01	0.238	8.54	0.481
iron	1.09	0.780	5.45	0.488	9.55	0.388
magnesium	6.58	0.087	14.20	0.028*	21.19	0.012*
phosphorus	1.31	0.728	5.95	0.429	10.20	0.335
potassium	2.88	0.410	7.32	0.292	9.71	0.374
sodium	1.43	0.699	3.72	0.714	10.57	0.307
zinc	1.98	0.577	3.39	0.759	9.96	0.353
copper	2.62	0.454	7.92	0.244	14.97	0.092
vitamin A - RE	2.79	0.425	7.19	0.304	9.41	0.400
thiamin	5.04	0.169	7.56	0.272	14.59	0.103
riboflavin	2.88	0.410	12.72	0.048*	17.86	0.037*
nicotinic acid	0.45	0.930	4.37	0.626	6.11	0.729
vitamin B6	0.77	0.857	11.10	0.085	7.31	0.044*
folic acid	2.70	0.440	6.28	0.393	7.59	0.576
ascorbic acid	0.72	0.869	3.06	0.801	5.04	0.831
pantothenic acid	2.19	0.533	4.72	0.581	5.75	0.765
biotin	3.71	0.294	16.56	0.011*	16.71	0.053*
vitamin D	1.12	0.773	4.72	0.581	5.82	0.758
vitamin E	2.29	0.514	5.48	0.484	13.33	0.148
manganese	1.82	0.610	3.56	0.736	8.96	0.441

* = statistically significant ($P<0.05$)

classification 1 = dmfs scores <0 or >0

classification 2 = dmfs scores 0,1-4, ≥5

classification 3 = dmfs scores 0,1-4,5-9,≥10

Table 4.35 Catmod analysis of dmfs score groups by quartiles of macronutrients - longitudinal group n=300

Nutrient	classification 1		classification 2		classification 3	
	x^2	P	x^2	P	x^2	P
energy	1.94	0.380	3.76	0.440	8.21	0.223
protein	0.99	0.805	3.17	0.787	3.54	0.939
fat	6.76	0.0809	8.22	0.222	9.84	0.363
cholesterol	0.78	0.855	5.66	0.463	9.25	0.414
total available carbohydrate	1.82	0.611	2.72	0.843	2.93	0.967
fibre	0.90	0.826	6.25	0.395	9.50	0.392
added sugar	2.38	0.497	4.09	0.665	8.33	0.501

* = statistically significant ($P<0.05$)

classification 1 = dmfs scores <0 or >0

classification 2 = dmfs scores 0,1-4, ≥ 5

classification 3 = dmfs scores 0,1-4,5-9,≥ 10

Table 4.36 Catmod analysis of dmfs score groups by quartiles of micronutrients - longitudinal group n=300

Nutrient	classification 1		classification 2		classification 3	
	x^2	P	x^2	P	x^2	P
calcium	2.39	0.496	8.17	0.226	9.93	0.356
vitamin B12	0.39	0.943	9.71	0.137	12.16	0.204
iron	2.75	0.433	8.77	0.187	9.55	0.388
magnesium	3.47	0.325	11.63	0.071	17.04	0.048*
phosphorus	0.86	0.835	6.21	0.401	8.58	0.477
potassium	1.25	0.741	4.86	0.562	5.15	0.821
sodium	1.85	0.605	4.81	0.569	7.40	0.596
zinc	0.77	0.856	3.05	0.803	6.17	0.723
copper	0.48	0.922	4.45	0.617	6.89	0.648
vitamin A - RE	0.97	0.810	4.03	0.673	4.36	0.886
thiamin	0.87	0.832	4.77	0.574	7.80	0.554
riboflavin	1.24	0.743	10.62	0.101	11.36	0.252
nicotinic acid	1.00	0.801	3.77	0.707	6.21	0.719
vitamin B6	0.97	0.809	5.54	0.477	10.48	0.313
folic acid	2.37	0.500	7.31	0.293	8.11	0.523
ascorbic acid	0.55	0.909	2.56	0.862	4.00	0.912
pantothenic acid	0.81	0.847	4.26	0.641	5.62	0.777
biotin	3.11	0.375	11.21	0.082	11.84	0.223
vitamin D	1.01	0.798	5.97	0.427	6.25	0.715
vitamin E	2.65	0.449	5.54	0.477	12.28	0.198
manganese	0.83	0.842	4.50	0.610	6.83	0.654

* = statistically significant ($P<0.05$)

classification 1 = dmfs scores <0 or >0

classification 2 = dmfs scores 0,1-4, ≥5

classification 3 = dmfs scores 0,1-4,5-9,≥10

When caries was classified according to classification 3 (4 dmfs score groups) and social class and educational level of the parents were included in the model to determine if these confounders had any additional effect on the macro- or micronutrient prediction of caries prevalence, only added sugar among the macronutrients (Table 4.37) and thiamin and vitamin B6 among the micronutrients (Table 4.38) showed an association with the prevalence of dental caries for the whole group of 5-year-old children, but social class or education level of the parents themselves showed no association for energy or any nutrient.

For the longitudinal group (Tables 4.39 and 4.40) only vitamin B12 was associated with the prevalence of dental caries when caries was classified according to classification 3 (4 dmfs score groups) with none of the macronutrients having an association.

In Tables 4.37- 4.40 the nutritional variable plus the two other variables (social class and education level), indented slightly, was a single test run; social class, education level and dmfs groupings (classifications 1, 2 and 3) as independent variables and the nutrients as dependent variables. The number of subjects were markedly reduced by the inclusion of social class and education level in the analysis due to lack of data available for some subjects.

Table 4.37 Catmod analysis of dmfs score groups by quartiles of macronutrients with social class and education level of parents included in model - whole group n=221

	classification 1			classification 2			classification 3		
variable	df	x^2	P	df	x^2	P	df	x^2	P
energy	2	3.04	0.219	4	3.76	0.440	6	10.15	0.118
social class	1	0.34	0.559	2	0.38	0.825	3	0.81	0.847
education level	2	0.46	0.793	4	4.93	0.295	6	6.52	0.367
protein	3	3.35	0.341	6	5.93	0.495	9	7.15	0.621
social class	1	0.02	0.882	2	0.03	0.986	3	0.14	0.986
education level	2	1.79	0.408	4	3.67	0.452	6	4.01	0.675
fat	3	6.53	0.088	6	10.88	0.092	9	12.51	0.186
social class	1	0.03	0.856	2	0.05	0.977	3	0.12	0.989
education level	2	1.25	0.535	4	3.64	0.457	6	3.78	0.709
cholesterol	3	1.22	0.748	6	5.59	0.471	9	6.93	0.644
social class	1	0.01	0.911	2	0.03	0.986	3	0.17	0.982
education level	2	1.26	0.531	4	3.77	0.439	6	4.02	0.674

Table 4.37(continued) Catmod analysis of dmfs score groups by quartiles of macronutrients with social class and education level of parents included in model - whole group n=221

	classification 1			classification 2			classification 3		
variable	df	x^2	P	df	x^2	P	df	x^2	P
total available									
carbohydrate	3	0.62	0.893	6	4.28	0.638	9	9.09	0.429
social class	1	0.00	0.971	2	0.00	0.999	3	0.07	0.995
education level	2	1.23	0.540	4	2.74	0.602	6	2.99	0.810
fibre	3	6.68	0.083	6	10.13	0.119	9	11.15	0.266
social class	1	0.00	0.957	2	0.03	0.984	3	0.17	0.982
education level	2	1.39	0.499	4	3.29	0.511	6	3.45	0.751
added sugar	3	3.79	0.285	6	8.24	0.22	9	17.14	0.047*
social class	1	0.03	0.868	2	0.03	0.984	3	0.30	0.959
education level	2	1.90	0.386	4	5.14	0.274	6	5.10	0.531

* = statistically significant ($P<0.05$)

classification 1 = dmfs scores <0 or >0

classification 2 = dmfs scores 0,1-4, ≥5

classification 3 = dmfs scores 0,1-4,5-9,≥10

Table 4.38 Catmod analysis of dmfs score groups by quartiles of micronutrients with social class and education level of parents included in model - whole group n=221

	classification 1			classification 2			classification 3		
variable	df	x^2	P	df	x^2	P	df	x^2	P
calcium	3	0.23	0.972	6	5.62	0.467	9	7.32	0.604
social class	1	0.01	0.937	2	0.01	0.994	3	0.12	0.989
education level	2	1.32	0.517	4	3.88	0.422	6	3.94	0.685
vitamin B12	3	0.38	0.945	6	7.97	0.240	9	11.56	0.240
social class	1	0.01	0.929	2	0.01	0.994	3	0.08	0.994
education level	2	1.21	0.545	4	3.50	0.478	6	3.69	0.718
iron	3	1.45	0.694	6	4.84	0.565	9	6.40	0.699
social class	1	0.02	0.883	2	0.05	0.977	3	0.17	0.982
education level	2	1.30	0.523	4	3.71	0.447	6	3.8	0.704
magnesium	3	5.65	0.130	6	10.89	0.092	9	12.21	0.202
social class	1	0.02	0.875	2	0.05	0.975	3	0.16	0.984
education level	2	1.31	0.520	4	2.97	0.562	6	3.06	0.801

Table 4.38 (continued) Catmod analysis of dmfs score groups by quartiles of micronutrients with social class and education level of parents included in model - whole group n=221

	classification 1			classification 2			classification 3		
variable	df	x^2	P	df	x^2	P	df	x^2	P
phosphorus	3	0.93	0.819	6	5.35	0.499	9	9.54	0.389
social class	1	0.00	0.962	2	0.01	0.995	3	0.04	0.998
education level	2	1.41	0.494	4	3.22	0.522	6	3.45	0.751
potassium	3	0.68	0.877	6	4.32	0.633	9	5.67	0.772
social class	1	0.00	0.979	2	0.00	0.999	3	0.10	0.992
education level	2	1.30	0.522	4	3.42	0.490	6	3.59	0.732
sodium	3	0.73	0.866	6	6.56	0.363	9	8.75	0.460
social class	1	0.01	0.903	2	0.02	0.990	3	0.09	0.993
education level	2	1.33	0.513	4	3.36	0.499	6	3.51	0.743
zinc	3	2.27	0.519	6	7.42	0.284	9	9.42	0.399
social class	1	0.03	0.860	2	0.03	0.985	3	0.10	0.992
education level	2	1.40	0.497	4	3.65	0.455	6	3.80	0.704
copper	3	1.33	0.713	6	3.79	0.706	9	4.90	0.843
social class	1	0.03	0.868	2	0.04	0.979	3	0.16	0.983
education level	2	1.44	0.486	4	3.29	0.511	6	3.50	0.744

Table 4.38 (continued) Catmod analysis of dmfs score groups by quartiles of micronutrients with social class and education level of parents included in model - whole group n=221

	classification 1			classification 2			classification 3		
variable	df	x^2	P	df	x^2	P	df	x^2	P
vitamin A (RE)	3	0.98	0.806	6	5.17	0.522	9	6.52	0.687
social class	1	0.01	0.933	2	0.03	0.985	3	0.20	0.978
education level	2	1.33	0.514	4	3.52	0.474	6	3.64	0.725
thiamin	3	6.67	0.083	6	11.48	0.075	9	16.61	0.055*
social class	1	0.01	0.942	2	0.02	0.992	3	0.04	0.998
education level	2	1.17	0.558	4	3.79	0.435	6	3.95	0.684
riboflavin	3	1.32	0.723	6	10.96	0.090	9	13.87	0.147
social class	1	0.02	0.875	2	0.06	0.970	3	0.14	0.986
education level	2	1.45	0.484	4	4.46	0.348	6	4.85	0.563
nicotinic acid	3	1.68	0.641	6	9.75	0.135	9	10.54	0.309
social class	1	0.03	0.871	2	0.10	0.950	3	0.20	0.977
education level	2	1.38	0.500	4	3.43	0.489	6	3.55	0.737
vitamin B6	3	0.38	0.945	6	6.34	0.387	9	18.72	0.028*
social class	1	0.01	0.910	2	0.02	0.992	3	0.02	0.999
education level	2	1.46	0.483	4	3.81	0.432	6	4.22	0.647

Table 4.38 (continued) Catmod analysis of dmfs score groups by quartiles of micronutrients with social class and education level of parents included in model - whole group n=221

	classification 1			classification 2			classification 3		
variable	df	x^2	P	df	x^2	P	df	x^2	P
folic acid	3	2.92	0.404	6	5.19	0.520	9	7.03	0.634
social class	1	0.03	0.874	2	0.08	0.963	3	0.27	0.965
education level	2	1.62	0.445	4	4.06	0.397	6	4.19	0.651
ascorbic acid	3	0.81	0.846	6	4.16	0.655	9	6.12	0.728
social class	1	0.02	0.898	2	0.05	0.977	3	0.20	0.977
education level	2	1.16	0.559	4	3.44	0.488	6	3.60	0.731
pantothenic acid	3	0.82	0.845	6	10.34	0.111	9	12.33	0.196
social class	1	0.02	0.876	2	0.07	0.964	3	0.33	0.955
education level	2	1.44	0.487	4	4.07	0.396	6	4.26	0.642
biotin	3	2.93	0.403	6	8.92	0.178	9	9.09	0.429
social class	1	0.01	0.916	2	0.02	0.992	3	0.12	0.989
education level	2	1.70	0.428	4	4.31	0.365	6	4.44	0.618
vitamin D	3	2.81	0.422	6	6.42	0.378	9	8.41	0.493
social class	1	0.00	0.962	2	0.03	0.987	3	0.33	0.954
education level	2	1.31	0.518	4	3.32	0.506	6	3.56	0.736

Table 4.38 (continued) Catmod analysis of dmfs score groups by quartiles of micronutrients with social class and education level of parents included in model - whole group n=221

	classification 1			classification 2			classification 3		
variable	df	x^2	P	df	x^2	P	df	x^2	P
vitamin E	3	1.19	0.755	6	6.55	0.364	9	9.08	0.430
social class	1	0.00	0.986	2	0.06	0.973	3	0.14	0.986
education level	2	1.07	0.586	4	3.50	0.478	6	3.86	0.695
manganese	3	3.89	0.274	6	8.70	0.191	9	10.77	0.292
social class	1	0.00	0.991	2	0.01	0.993	3	0.16	0.983
education level	2	1.33	0.514	4	3.92	0.417	6	4.00	0.676

* = statistically significant ($P<0.05$)

classification 1 = dmfs scores <0 or >0

classification 2 = dmfs scores 0,1-4, ≥5

classification 3 = dmfs scores 0,1-4,5-9,≥10

Table 4.39 Catmod analysis of dmfs score groups by quartiles of macronutrients with social class and education level of parents included in model - longitudinal group n=142

	classification 1			classification 2			classification 3	
variable	df	x^2	P	df	x^2	P	df	x^2	P
energy	2	0.04	0.978	4	0.42	0.981	6	1.75	0.941
social class	1	0.98	0.321	2	1.31	0.519	3	1.54	0.673
education level	2	2.23	0.328	4	3.91	0.418	6	4.72	0.580
protein	3	3.35	0.341	6	8.25	0.220	9	8.75	0.461
social class	1	0.18	0.672	2	0.82	0.665	3	0.92	0.821
education level	2	2.37	0.305	4	3.39	0.495	6	3.66	0.722
fat	3	4.22	0.239	6	7.11	0.311	9	7.46	0.589
social class	1	0.05	0.829	2	0.58	0.749	3	0.66	0.883
education level	2	1.29	0.523	4	2.39	0.605	6	2.69	0.847
cholesterol	3	1.46	0.692	6	5.29	0.508	9	8.84	0.452
social class	1	0.23	0 634	2	0.76	0.684	3	1.07	0.784
education level	2	1.70	0.426	4	3.20	0.525	6	3.53	0.741

Table 4.39 (continued) Catmod analysis of dmfs score groups by quartiles of macronutrients with social class and education level of parents included in model - longitudinal group n=142

	classification 1			classification 2			classification 3		
variable	df	x^2	P	df	x^2	P	df	x^2	P
total available									
carbohydrate	3	3.31	0.347	6	6.25	0.396	9	7.69	0.566
social class	1	0.37	0.545	2	0.76	0.685	3	0.79	0.851
education level	2	2.43	0.297	4	2.80	0.592	6	2.94	0.816
fibre	3	2.93	0.403	6	7.35	0.290	9	8.39	0.496
social class	1	0.23	0.631	2	0.84	0.657	3	0.95	0.814
education level	2	1.81	0.405	4	3.20	0.525	6	3.49	0.746
added sugar	3	1.34	0.743	6	3.87	0.694	9	8.13	0.521
social class	1	0.15	0.696	2	0.80	0.669	3	0.89	0.828
education level	2	1.48	0.477	4	2.48	0.649	6	2.61	0.856

* = statistically significant ($P<0.05$)

classification 1 = dmfs scores <0 or >0

classification 2 = dmfs scores 0,1-4, ≥5

classification 3 = dmfs scores 0,1-4,5-9,≥10

Table 4.40 Catmod analysis of dmfs score groups by quartiles of micronutrients with social class and education level of parents included in model - longitudinal group n=142

	classification 1			classification 2			classification 3		
variable	df	x^2	P	df	x^2	P	df	x^2	P
calcium	3	0.16	0.984	6	7.34	0.291	9	8.77	0.459
social class	1	0.26	0.612	2	0.89	0.642	3	1.05	0.789
education level	2	1.54	0.463	4	3.01	0.556	6	3.24	0.778
vitamin B12	3	4.91	0.178	6	16.50	0.011*	9	21.79	0.010*
social class	1	0.37	0.544	2	0.52	0.772	3	0.57	0.902
education level	2	2.51	0.286	4	3.43	0.489	6	3.46	0.749
iron	3	1.20	0.753	6	3.92	0.687	9	5.85	0.755
social class	1	0.22	0.636	2	0.61	0.738	3	0.82	0.844
education level	2	1.69	0.430	4	3.02	0.554	6	3.34	0.765
magnesium	3	0.94	0.817	6	5.22	0.516	9	6.58	0.681
social class	1	0.0	0.651	2	1.04	0.594	3	1.17	0.760
education level	2	1.29	0.524	4	2.47	0.650	6	2.72	0.843

Table 4.40 (continued) Catmod analysis of dmfs score groups by quartiles of micronutrients with social class and education level of parents included in model - longitudinal group n=142

	classification 1			classification 2			classification 3		
variable	df	x^2	P	df	x^2	P	df	x^2	P
phosphorus	3	2.03	0.566	6	5.67	0.461	9	9.33	0.408
social class	1	0.12	0.731	2	0.46	0.793	3	0.47	0.926
education level	2	1.78	0.410	4	2.65	0.618	6	2.81	0.833
potassium	3	0.75	0.861	6	2.83	0.830	9	4.74	0.856
social class	1	0.18	0.673	2	0.75	0.686	3	0.95	0.814
education level	2	1.37	0.505	4	2.54	0.638	6	2.85	0.828
sodium	3	0.31	0.958	6	4.62	0.593	9	6.00	0.740
social class	1	0.20	0.651	2	0.75	0.689	3	0.85	0.837
education level	2	1.54	0.463	4	2.48	0.648	6	2.78	0.835
zinc	3	2.10	0.552	6	7.81	0.252	9	9.13	0.425
social class	1	0.17	0.684	2	0.49	0.783	3	0.57	0.904
education level	2	2.31	0.314	4	3.61	0.462	6	3.82	0.701
copper	3	0.50	0.919	6	1.14	0.980	9	1.65	0.996
social class	1	0.25	0.617	2	0.89	0.640	3	1.07	0.785
education level	2	1.65	0.437	4	2.59	0.628	6	2.86	0.826

Table 4.40 (continued) Catmod analysis of dmfs score groups by quartiles of micronutrients with social class and education level of parents included in model - longitudinal group n=142

	classification 1			classification 2			classification 3		
variable	df	x^2	P	df	x^2	P	df	x^2	P
vitamin A (RE)	3	2.62	0.454	6	7.43	0.283	9	7.92	0.542
social class	1	0.25	0.620	2	0.98	0.611	3	1.16	0.764
education level	2	1.74	0.418	4	2.49	0.646	6	2.84	0.828
thiamin	3	1.17	0.759	6	4.30	0.636	9	6.05	0.735
social class	1	0.22	0.640	2	0.71	0.701	3	0.77	0.856
education level	2	1.54	0.463	4	2.89	0.577	6	3.28	0.773
riboflavin	3	6.16	0.104	6	14.25	0.027*	9	14.45	0.107
social class	1	0.27	0.604	2	0.71	0.702	3	0.84	0.840
education level	2	1.88	0.391	4	3.47	0.483	6	3.72	0.715
nicotinic acid	3	1.96	0.581	6	4.97	0.548	9	5.40	0.789
social class	1	0.09	0.763	2	0.47	0.790	3	0.57	0.902
education level	2	1.29	0.524	4	2.59	0.629	6	2.8[illegible]	0.825
vitamin B6	[illegible]	0.56	0.907	6	2.87	0.825	9	11.26	0.258
social class	1	0.19	0.666	2	0.84	0.657	3	0.86	0.834
education level	2	1.25	0.536	4	2.37	0.668	6	3.16	0.789

Table 4.40 (continued) Catmod analysis of dmfs score groups by quartiles of micronutrients with social class and education level of parents included in model - longitudinal group n=142

	classification 1			classification 2			classification 3		
variable	df	x^2	P	df	x^2	P	df	x^2	P
folic acid	3	0.75	0.861	6	2.45	0.874	9	4.25	0.901
social class	1	0.24	0.625	2	1.15	0.564	3	1.35	0.718
education level	2	1.73	0.420	4	3.07	0.546	6	3.39	0.759
ascorbic acid	3	1.50	0.682	6	4.05	0.670	9	5.15	0.821
social class	1	0.26	0.613	2	1.15	0.564	3	1.31	0.726
education level	2	1.43	0.490	4	2.75	0.601	6	3.06	0.801
pantothenic acid	3	3.11	0.376	6	11.58	0.071	9	12.46	0.189
social class	1	0.27	0.607	2	0.96	0.619	3	1.08	0.781
education level	2	2.31	0.315	4	4.03	0.402	6	4.24	0.644
biotin	3	4.84	0.184	6	9.94	0.127	9	11.48	0.244
social class	1	0.53	0.465	2	1.05	0.591	3	1.30	0.729
education level	2	1.90	0.386	4	3.63	0.459	6	3.86	0.696
vitamin D	3	5.05	0.168	6	8.80	0.185	9	10.80	0.290
social class	1	0.26	0.608	2	0.90	0.638	3	1.22	0.749
education level	2	1.73	0.422	4	2.74	0.602	6	3.08	0.799

Table 4.40 (continued) Catmod analysis of dmfs score groups by quartiles of micronutrients with social class and education level of parents included in model - longitudinal group n=142

	classification 1			classification 2			classification 3		
variable	df	x^2	P	df	x^2	P	df	x^2	P
vitamin E	3	0.93	0.818	6	5.86	0.439	9	7.71	0.563
social class	1	0.25	0.616	2	1.06	0.589	3	1.16	0.762
education level	2	1.33	0.514	4	2.25	0.690	6	2.48	0.870
manganese	3	4.72	0.193	6	10.48	0.106	9	1.73	0.229
social class	1	0.23	0.633	2	0.84	0.657	3	0.97	0.808
education level	2	2.16	0.339	4	4.08	0.395	6	4.38	0.626

* = statistically significant ($P<0.05$)

classification 1 = dmfs scores <0 or >0

classification 2 = dmfs scores 0,1-4, ≥5

classification 3 = dmfs scores 0,1-4,5-9,≥10

4.3.4 Energy, macro- and micronutrient intake in relation to the incidence of dental caries - Regression analysis results

Regression analysis determined if any macro- or micronutrient influenced the incidence of dental caries among the whole group of 5-year-old urban black children as well as among the longitudinal group.

Confounding variables, namely, social class and educational level of the parents were included in the model to see if they had any additional influence in macro- and micronutrients predicting dental caries.

It was mentioned in the methods chapter that hunting for mildly significant effects in a large number of analyses is not scientifically justified. Therefore only the results of the regression analysis against the transformation of log(dmfs+k) will be shown, This analysis appeared to give the best results and there was rationale behind the selection of families of transformation.

The following figure (Fig.4.2) shows the subject numbers for the regression analysis for the whole and longitudinal group and Tables 4.41-4.48 show the results of the regression analysis on these groups.

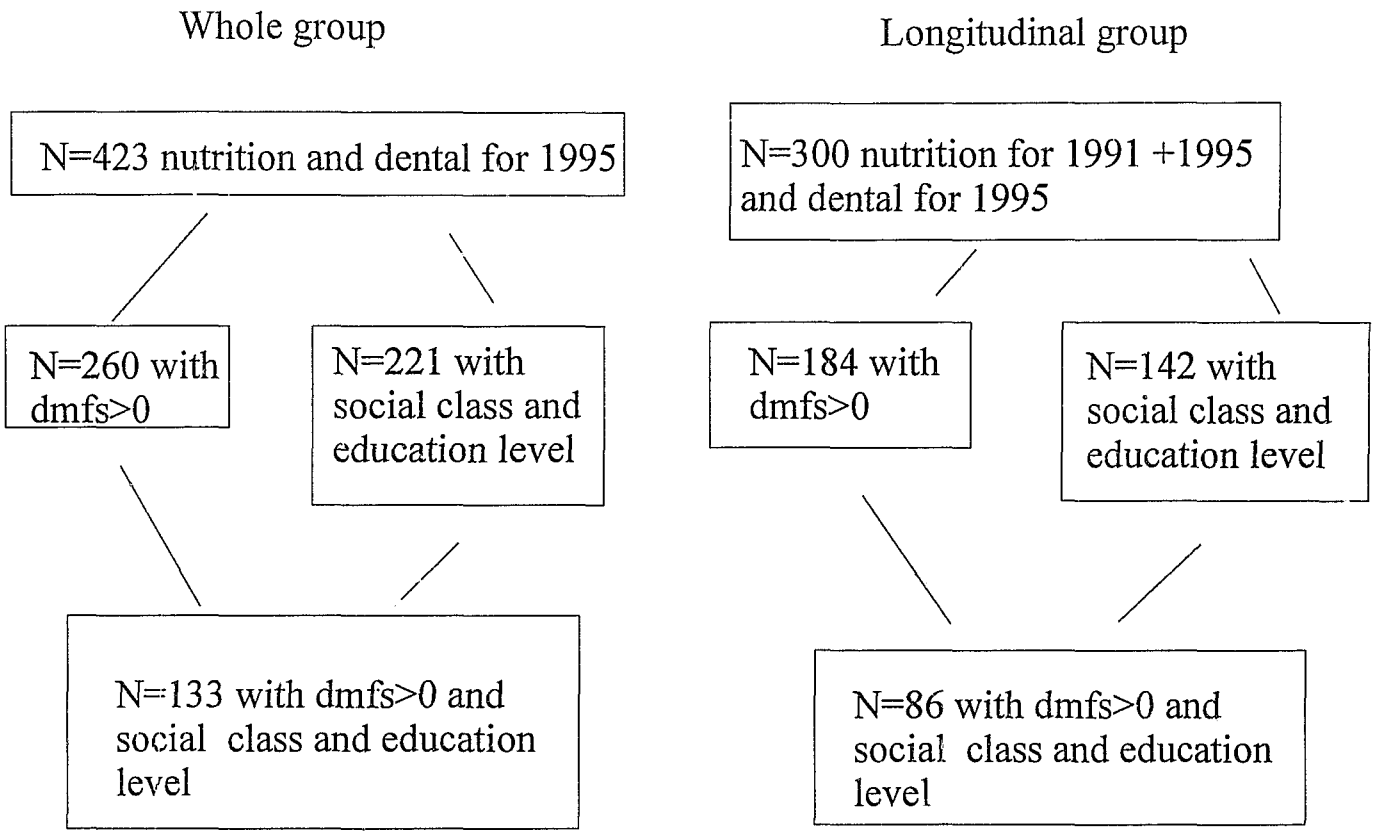

Figure 4.2 Subject numbers for regression analysis

Regression analysis of the whole group of 5-year-old children with nutrition and dental information for 1995 (n=423) showed energy, protein, fat, cholesterol and total available carbohydrate to be associated with the incidence of dental caries. These nutrients showed no association for the longitudinal group.(Table 4.41).

No micronutrients were found to influence dental caries for either the whole or longitudinal groups (Table 4.42).

Table 4.41 Regression analysis for all subjects and variables against log(dmfs+k) with social class and parents education level excluded in the analysis

I. macronutrients

variable	whole group n=423, k=0.275		longitudinal group n=300, k=0.3	
	parameter estimates	P value	parameter estimates	P value
energy	0.047	0.043*	0.023	0.432
protein	-0.229	0.022*	-0.119	0.381
fat	-0.443	0.031*	-0.231	0.377
cholesterol	-0.009	0.026*	0.011	0.047
total available carbohydrate	-0.196	0.032*	-0.109	0.335
fibre	-0.060	0.463	-0.006	0.948
added sugar	0.010	0.183	0.013	0.211

* = statistically significant ($P<0.05$)

Table 4.42 Regression analysis for all subjects and variables against log(dmfs+k) with social class and parents education level excluded in the analysis

II. micronutrients

variable	whole group n=423, k=0.275		longitudinal group n=300, k=0.3	
	parameter estimates	P value	parameter estimates	P value
calcium	0.005	0.080	0.004	0.237
vitamin B12	-0.308	0.602	-0.264	0.703
iron	-0.106	0.592	0.083	0.740
magnesium	0.001	0.946	-0.009	0.546
phosphorus	-0.000	0.983	0.004	0.493
potassium	-0.000	0.841	0.000	0.829
sodium	0.000	0.807	-0.000	0.712
zinc	0.249	0.455	-0.187	0.687
copper	2.490	0.141	3.455	0.089
vitamin A (RE)	0.000	0.982	-0.000	0.773
thiamin	2.254	0.253	2.933	0.243
riboflavin	-0.727	0.783	-0.480	0.881
nicotinic acid	-0.087	0.543	-0.026	0.883
vitamin B6	-0.127	0.810	-0.289	0.663
folic acid	-0.002	0.729	-0.010	0.146
ascorbic acid	0.002	0.791	0.009	0.230
pantothenic acid	-0.384	0.536	-0.691	0.343
biotin	-0.124	0.198	-0.138	0.223
vitamin D	-0.006	0.927	-0.049	0.552
vitamin E	0.056	0.085	0.056	0.172
manganese	0.596	0.279	0.962	0.148

*statistically significant (P<0.05)

When the children with caries only (dmfs>0) in these groups were analysed the situation was reversed for the groups. Energy, fat and total available carbohydrate were found to be associated with dental caries incidence in the longitudinal group, with only total available carbohydrate being associated for the whole group (Table 4.43).

Among the micronutrients (Table 4.44) ascorbic acid (P<0.058) was almost associated for the longitudinal group of 5-year-olds with caries.

Table 4.43 Regression analysis for subjects with caries (dmfs>0) and all variables against log(dmfs+k) excluding social class and education level in the analysis

I. macronutrients

variable	whole group n=260, k=0.275		longitudinal group n=184, k=0.3	
	parameter estimates	P value	parameter estimates	P value
energy	0.032	0.076	0.042	0.051*
protein	-0.063	0.427	-0.095	0.283
fat	-0.280	0.073	-0.370	0.048*
cholesterol	-0.001	0.787	-0.002	0.586
total available carbohydrate	-0.131	0.059*	-0.164	0.046*
fibre	0.022	0.685	0.010	0.874
added sugar	0.006	0.537	-0.003	0.689

* = statistically significant (P<0.05)

Table 4.44 Regression analysis for subjects with caries (dmfs>0) and all variables against log(dmfs + k) excluding social class and education level in the analysis

II. micronutrients

variable	whole group n=260, k=0.275		longitudinal group n=184, k=0.3	
	parameter estimates	P value	parameter estimates	P value
calcium	-0.001	0.741	-0.003	0.288
vitamin B12	-0.165	0.682	0.361	0.445
iron	-0.234	0.143	-0.089	0.629
magnesium	-0.000	0.962	-0.000	0.986
phosphorus	-0.003	0.468	-0.001	0.725
potassium	-0.001	0.463	-0.000	0.704
sodium	-0.000	0.653	0.000	0.704
zinc	-0.251	0.309	-0.089	0.629
copper	2.087	0.066	2.030	0.128
vitamin A (RE)	0.000	0.883	0.000	0.501
thiamin	0.948	0.488	-1.261	0.456
riboflavin	3.363	0.065	3.802	0.078
nicotinic acid	-0.158	0.120	-0.133	0.246
vitamin B6	-0.205	0.563	-0.457	0.311
folic acid	-0.002	0.611	-0.005	0.342
ascorbic acid	0.007	0.094	0.009	0.058*
pantothenic acid	-0.724	0.134	-0.809	0.165
biotin	0.018	0.827	0.045	0.661
vitamin D	-0.025	0.601	-0.012	0.820
vitamin E	0.001	0.961	-0.000	0.995
manganese	0.706	0.086	0.692	0.131

*statistically significant (P<0.05)

It was found that by including social class and education level of the parents in the analysis increased the association of energy, protein, fat and total carbohydrate among the macronutrients with the incidence of dental caries for the whole group, with the total available carbohydrate showing the highest association ($P<0.012$) (Table 4.45). These nutrients were however not associated with caries for the longitudinal group.

None of the micronutrients (Table 4.46) showed any association for either the whole or longitudinal group of children when social class and educational level were included in the analysis.

Table 4.45 Regression analysis for all subjects and variables against log(dmfs+k) with social class and parents education level included in the analysis

I. macronutrients

variable	whole group n=221, k=0.275		longitudinal group n=142, k=0.3	
	parameter estimates	P value	parameter estimates	P value
social class	-0.074	0.802	-0.004	0.990
education level	-0.167	0.409	0.104	0.700
energy	0.088	0.013*	0.084	0.116
protein	-0.321	0.031*	-0.181	0.488
fat	-0.748	0.015*	-0.701	0.138
cholesterol	-0.006	0.381	-0.010	0.348
total available carbohydrate	-0.344	0.012*	-0.341	0.095
fibre	-0.080	0.485	0.101	0.522
added sugar	0.005	0.646	0.011	0.562

* = statistically significant (P<0.05)

Table 4.46 Regression analysis for all subjects and variables against log(dmfs + k) with social class and parents education level included in the analysis

II. micronutrients

variable	whole group n=221, k=0.275		longitudinal group n=142, k=0.3	
	parameter estimates	P value	parameter estimates	P value
calcium	0.004	0.402	0.004	0.447
vitamin B12	-1.135	0.198	-0.505	0.669
iron	-0.396	0.167	-0.224	0.455
magnesium	-0.007	0.740	-0.018	0.545
phosphorus	-0.005	0.562	-0.001	0.933
potassium	-0.001	0.449	-0.003	0.191
sodium	-0.000	0.819	-0.001	0.584
zinc	0.483	0.307	-0.583	0.708
copper	3.428	0.159	4.514	0.188
vitamin A (RE)	-0.000	0.569	-0.001	0.418
thiamin	-2.438	0.387	-2.008	0.667
riboflavin	1.907	0.605	2.882	0.560
nicotinic acid	-0.170	0.410	-0.261	0.414
vitamin B6	1.035	0.190	1.794	0.124
folic acid	0.013	0.127	0.004	0.710
ascorbic acid	-0.003	0.692	0.011	0.302
pantothenic acid	-1.007	0.271	-1.857	0.134
biotin	0.251	0.169	0.253	0.334
vitamin D	-0.067	0.511	-0.083	0.547
vitamin E	-0.030	0.530	-0.060	0.395
manganese	0.392	0.661	0.877	0.600

Including social class and education level of the parents in the analysis of children with caries only showed no macro- or micronutrient to be associated with dental caries for either the whole or longitudinal groups (Tables 4.47 and 4.48).

Table 4.47 Regression analysis for subjects with caries (dmfs>0) and all variables against log(dmfs+k) including social class and education level in the analysis
I. macronutrients

variable	whole group n=133, k=0.275		longitudinal group n=86, k=0.3	
	parameter estimates	P value	parameter estimates	P value
social class	0.060	0.774	-0.013	0.962
education level	-0.233	0.115	-0.060	0.770
energy	0.033	0.213	0.058	0.144
protein	-0.030	0.816	-0.165	0.375
fat	-0.289	0.218	-0.513	0.142
cholesterol	-0.022	0.646	-0.006	0.385
total available carbohydrate	-0.132	0.197	-0.210	0.163
fibre	0.045	0.578	0.033	0.800
added sugar	0.001	0.891	-0.019	0.225

* = statistically significant (P<0.05)

Table 4.48 Regression analysis for subjects with caries (dmfs>0) and all variables against log(dmfs+k) including social class and education level in the analysis

II. micronutrients

variable	whole group n=133, k=0.275		longitudinal group n=86, k=0.3	
	parameter estimates	P value	parameter estimates	P value
calcium	0.002	0.568	0.000	0.945
vitamin B12	-0.680	0.259	0.041	0.961
iron	-0.162	0.519	-0.162	0.618
magnesium	-0.005	0.741	0.005	0.796
phosphorus	-0.008	0.144	-0.004	0.639
potassium	0.000	0.769	-0.002	0.380
sodium	-0.000	0.860	0.001	0.301
zinc	-0.214	0.601	-0.080	0.888
copper	0.440	0.781	-0.735	0.731
vitamin A (RE)	-0.000	0.926	0.001	0.412
thiamin	1.431	0.510	-3.395	0.359
riboflavin	3.361	0.200	2.197	0.517
nicotinic acid	-0.122	0.504	0.024	0.925
vitamin B6	-0.364	0.525	0.242	0.771
folic acid	-0.000	1.00	0.003	0.732
ascorbic acid	0.002	0.707	0.006	0.451
pantothenic acid	-0.663	0.354	-0.973	0.329
biotin	0.133	0.298	0.187	0.294
vitamin D	-0.048	0.525	-0.009	0.930
vitamin E	-0.004	0.900	0.010	0.840
manganese	0.650	0.408	-0.690	0.581

*statistically significant (P<0.05)

4.4 Discussion

4.4.1 Main findings

4.4..1.1 Credibility of study group within the Birth-to Ten

The Kruskal-Wallis test showed that urban black South African children that had nutrition information in 1991 and 1995 and/or dental information for 1995 were nutritionally representative of the groups that only had nutrition information at 1991 and 1995 for most nutrients. Exceptions were vitamin D and ascorbic acid. By 1995 when caries had developed children with nutrition information for 1991 and 1995 and dental information for 1995 were not significantly different from those that only had nutrition information for 1991 and 1995. The credibility testing for this study thus showed that the study group was a representative sample of urban black South African children in the Birth-to-Ten study at 5-years.

4.4.1.2 Prevalence of caries

The Mantel-Haenszel x^2 test for trend showed energy, fat, fibre and added sugar (nutrient quartiles), and fat, cholesterol and added sugar (nutrient thirds) to be associated with caries prevalence for all the 5-year-old urban black children. Among the micronutrients calcium, vitamins B12 and A and riboflavin (nutrient quartiles) and calcium, riboflavin, vitamins E and B12 (nutrient thirds) showed an association with prevalence. For the longitudinal group, however, only energy (nutrient quartiles) among the macronutrients and riboflavin, vitamin E (nutrient thirds) and calcium (nutrient quartiles and thirds) were found to be associated with caries prevalence.

However, with no definite pattern emerging in the frequency distribution of these nutrients the association was probably isolated and of no clinical relevance, being mathematical possibly due to subject number.

The Catmod analysis showed that the presence or absence of caries among all the 5-year-old children was associated with energy intake, fat, magnesium, riboflavin, biotin and vitamin B6 and for the longitudinal group only magnesium when social class and education level of the parents were excluded from the model. Including these factors in the model resulted in added sugar, thiamin and vitamin B6 to be associated with caries prevalence among the whole group and only vitamin B12 for the longitudinal group.

4.4.1.3 Incidence of caries

Regression analysis of the whole group of 5-year-olds with nutrition and dental information for 1995 showed energy, protein, fat, cholesterol and total available carbohydrate to be associated with the incidence of dental caries. These nutrients showed no association for the longitudinal group. However, when the children with caries only were analysed the situation was reversed and the above nutrients were only associated with dental caries incidence among the longitudinal group, with the exception of total available carbohydrate that was associated for both the whole and longitudinal groups. Among the micronutrients ascorbic acid was associated with caries incidence among the longitudinal group with caries only.

When social class and education level of the parents were included in the analysis energy, protein, fat and carbohydrate were still found to be associated for the whole group of

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When social class and education level of the parents were included in the analysis energy, protein, fat and carbohydrate were still found to be associated for the whole group of

children, but when these factors were included in analysing the groups with caries only, no macro- or micronutrient was found to be associated with dental caries incidence for either the whole or longitudinal groups.

Macronutrients appeared to have a greater influence on the dental health of 5-year-old urban black South African children than the micronutrients.

4.4.2 Social and dietary factors as predictors of dental caries

Knowledge concerning the value of dietary habits for predicting caries seems to be limited and unclear. One reason may be that the complexity of the diet, exemplified for instance by intake frequency, amount of fermentable carbohydrates, consistency and stickiness has never been expressed in a comprehensive index (276). Another reason is that the interactive effect of a number of confounders has mostly been overlooked (276). In addition there is great inter- and intra individual variation in nutrient intake and the lack of established correlations between the frequency of consumption and specific effects on the children can be attributed in part to the questionable reliability of the dietary information obtained. Caries found at the time of the examination is the result of past as well as present eating habits. Some of these problems can be avoided by obtaining information from both the child and the mother or guardian. However, in the BTT study only the answers of the parents or guardians could be relied upon as the children were too young to answer the dietary questionnaire. This possibly resulted in some inaccuracy in the dietary assessment but all dietary intake methods are only an estimate and for group analysis on large samples as in the BTT study this error was eliminated to a large extent. It is apparent though that diet is

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extremely difficult to measure with any degree of accuracy. In addition caries was assessed at 1- and 5-years and dietary intake at 1-year was compared with caries incidence at 5-years among the same children. This allowed for the fact that caries is progressive, developing over a period of time, and is a result of both past and present dietary intake.

There is no gold standard for diagnosis of caries so there is some degree of imprecision about measuring the response variable itself. As such the disease itself is not being measured but in reality a proxy variable. Because of this there may be problems in determining the strength of association between various risk factors and dental caries. When we consider the fact that all the risk factors thought so far to be of interest are themselves very difficult to measure it must be appreciated that the issue is very complex. If the risk factors cannot be measured directly or accurately then the measurement error involved will be unavoidably large. Even if the causative relationship between the risk factor and caries were very strong satisfactory statistical analysis would only show a weak association (276), as found with many of the dietary and social factors in the BTT Study.

It is unclear whether in fact increasing the accuracy of the measurement of the food items consumed is likely to help since the nutrient content and amounts consumed nevertheless remain a proxy for what actually occurs at the tooth surface (277).

During the past 20 years the ability to predict caries incidence has been the subject of many studies (278). A number of different criteria like caries prevalence, oral hygiene and diet, different salivary factors and the number of salivary streptococci and lactobacilli have been

used to predict future caries incidence. None of them has been found to be completely satisfactory and there is no convincing evidence that one variable is superior to the others. This is possibly due to different designs and validating and screening criteria used in the studies. Furthermore it is more difficult to predict a rare phenomenon than a common one. This means that tests compiled to predict caries incidence in a population where the incidence of dental decay is high will be of less value in a population where the incidence is low. Therefore different factors found to be rather good caries predictors in the early 1970s might be poor predictors today (278).

Risk indicators are helpful in identifying groups at risk for developing caries but they give little information about the causes of differences in caries experience (279). If diet alone or any other risk factor alone is considered in predicting caries the selection of high risk individuals will be less efficient. But if data concerning the risk factors in the individual are added to the dietary information the number of individuals correctly classified with regard to caries will increase considerably (280). In an epidemiologic investigation on the effect of a particular risk factor, the problem of distinguishing this effect from that of confounding factors is often a major one. The number of risk factors associated with the development of dental caries is beyond the scope for discussion in this thesis but, social and dietary factors that were included in the project will be discussed with special reference to the situation in South Africa, a developing country, and results from the developed countries in Europe and America.

4.4.2.1 Social factors

To allow for future developments in South Africa many more demands are being placed on the national health care budget than can be satisfied (156). In such circumstances those most at risk of disease should be targeted to make best use of available resources. One way to target individuals at high risk to dental caries is to use social factors as caries predictors (281). A number of studies have documented the effect of socio-demographic factors on dental caries experience. Social factors that have been reported to be indicators of risk for dental caries in children include parental education, (279,282-284), social class (285) and the number of children per family (286). Savara and Suher (287), as early as 1955, reported a negative association between parents education level and the caries experience of children 1-6-years. More recently Calache (288), studying the oral health of 4-year-old children in Brunswick, reported that the majority of children with high restorative treatment needs had mothers with a low level of education. Another study (289) on the diet and feeding patterns in high risk preschool children aged 3-5-years showed that the best single predictor of variance in caries experience of subjects explaining 23% of the variance in dmfs, was the mothers level of education. A longitudinal study of infant feeding practice, diet and caries, related to social class in British children aged 3 and 8-10-years (121) found a positive correlation between reported poor infant feeding practices and caries experience at age 3 and at 8-10-years. Analysis of the caries experience of the cohort by social class showed that the pronounced class gradient, so evident at 3-years, was still discernible 6 years later in the deciduous teeth. These findings are consistent with the majority of cross-sectional studies undertaken in Britain (290,291). Dental caries in the primary dentition was investigated in 6-year-old British children (292). The dental health behaviour and social

characteristics of the mother were determined by an initial investigation at birth and a second interview and clinical examination at 6-years. Caries experience was also found to be related to maternal social characteristics such as the mothers social class, her age at first pregnancy and the age at which she completed her education. It was thus possible to identify in infancy several maternal characteristics which were associated with variations in subsequent caries experience in the primary dentition thus providing a means for health educators to identify vulnerable children and their parents before disease had occurred (292). A dental health survey was also included as part of a large scale study of nutrition in British preschool children 1.5 -4.5-years and showed that 17% of the children had some caries experience that increased with age affecting 30% of the 3.5-4.5-year-olds (mean dmft was 1.3). Dental decay was most strongly related to social background and the factors most strongly related to caries prevalence were the educational level of the mother in the 2.5-3.5 age group and head of the household in the 3.5-4.5 age group. Multivariate analysis confirmed the relationship between caries prevalence and social factors (293).

Similar results have been found in other countries (294). Forty-three variables were included in a theoretical model of the caries process among adolescent populations in Canada. Four multiple regression analyses were performed to uncover significant explanatory factors for DMFT index, plaque index, frequency of sweet consumption between meals and frequency of sweet consumption at meals. Each analysis produced a significant R^2 explaining respectively, 29%, 15%, 74% and 62% of the variance. The results demonstrated the contribution of the different factors included in the proposed model. They suggested that plaque index was by far the most significant factor of the DMFT index. In

turn the plaque index was best accounted for by the level of the fathers schooling, used as an indicator of the family's socioeconomic status. The lower the level of education the higher the plaque index. Sweets consumption was a significant determinant of caries experience independent of any relation to plaque index. Mothers education was negatively related to DMFT which is consistent with the inverse relationship shown between the plaque index and the level of the fathers schooling (294).

Contemporary evidence from Africa generally has shown a higher prevalence and severity of caries among children from the upper socio-economic backgrounds (44), a relationship opposite to that in Europe. In South Africa two studies have found an inverse relationship between dental caries, parental education and social class in the white community (295,296). However, similar information for black children is not available, but a recent study in South Africa (41) investigating the association between dental caries prevalence and severity and social factors among 3-5-year-old black children found that family education was associated with caries prevalence and severity and the study concluded that family education was a disease marker to target in future caries risk evaluations. The fairly high caries prevalence but low mean dmfs scores in Khan's (41) study are similar to trends reported elsewhere in Africa (42-45), but differs from most African investigations in that observed caries rates decreased as family education increased, a typical westernised pattern. Social class, mostly based on the occupation of the parent, has been examined for its effects on caries in several studies in Africa with inconsistent findings. Caries was found to be significantly worse in higher social classes in Nigeria (297,298) and Sierra Leone (299). Khan's (41) study found no statistically significant effect, an assessment shared by

researchers in Kenya (43), Sudan (300) and Tanzania (301).

The way in which individuals with different educational levels are grouped influences the statistical analysis. It is thought that the general *milieu of the family in South Africa is* probably more important than the education level of one parent. A feature of families in developing communities in South Africa is that the father, regarded as the head of the household, frequently has less education than the mother. Due to pressure to earn money early in life, males leave school earlier than females. The combined parental education level at home thus seems a more appropriate measure. Clearly different ethnic groups living in the same country can have different social markers for the same disease. This possibility was shown recently when 12-year-old South African Indian and white groups were compared for dental caries using the same social markers. In the Indian community no statistically significant social markers were seen, in contrast to three in the white group - namely social class, family income and crowding (295). One reason for a lack of identified social markers in Africans could be that the wrong markers or methods have been used up to now because investigations apply factors or classifications applicable to Europe and other western countries. No assessments appropriate for African populations have been defined. Clearly defined classifications were, however, used in Khan's study (41). Kh ~ (41) concluded that family education grouping should be used in prospective studies of dental caries risk groups in South African children. Although Khan's (41) study comprised the same age group, South African community and classification of social factors as the BTT study, diet was not included as a variable in her study and true comparisons cannot be made. Similarly, most of the other studies on caries and social factors, particularly in South Africa, have not

included dietary intake as a confounding factor therefore no comparisons can be made. The BTT Study showed that by including social class and education level of the parents in a regression analysis increased the significance of energy, protein, fat and total available carbohydrate in the incidence of caries for the whole group of 5-year-olds only. The social factors as confounders in the incidence of dental caries did not form a major part of this thesis therefore only a brief discussion has been pursued, keeping in mind that the entire caries process is very complex and multifactorial. In addition the results of the BTT Study clearly showed that by including social class and education level of the parents in the model had very little significant influence on the nutrient intake on caries incidence and the preceding points mentioned possibly accounted for the low statistical significance of social factors in the BTT Study.

Another factor of concern, particularly in Africa, is poverty and material deprivation. Evidence has accumulated on the issue of inequalities in health and the links between public health and material conditions. Yet, if improvements in health are generally attributed to rising living standards, so worsening health among some groups and widening differentials must be related primarily to changes in the same factors (302) The existence and extensive nature of this problem associated with dental disease has been described, and reinforces the concept that deprivation and poverty, two conditions that are unlikely to change in the near future in South Africa, are associated with increased risk to dental disease (303). With a quarter of the children accounting for three quarters of caries present, Mitropoulos (304) suggested that less effort should be made to identify individuals and that factors should be researched which would lead to the identification of groups of children at risk to dental

caries so that preventive action could be directed where needs were greatest. Research has indeed shown that significant differences existed between high, middle and low ranges of material deprivation among 5-year-old children in County Durham and that the index of material deprivation could indicate groups of children in the community at high and low risk of dental caries (305). More recently the influence of social deprivation upon diet and dental health was investigated among 5-year-old children in north and west Belfast, Ireland. Unemployment and parental attitudes were important determinants of dental caries in these children (306). One cannot deny that material deprivation must have also influenced caries incidence among the 5-year-old urban black children in the BTT study, being a former deprived community in South Africa.

The other risk factor, dietary intake in relation to caries formed the major part of this thesis

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4.4..2.2. Food and nutrient intake in relation to dental caries

a) Energy and macronutrient intake

Many publications have assessed the influence of diet on dental caries in the permanent dentition but dietary influences on primary dentition caries have not been studied widely (34,293); not in large samples (293), and particularly not in longitudinal studies (72). In addition no South African study has been able to compare the association between diet and dental caries incidence in cross-sectional and longitudinal subjects in the same longitudinal cohort. The information from this study is thus unique and true comparisons with other studies can therefore not be made.

Studies on the association between diet and dental caries have used dietary records (34,293) and/or 24-hour recalls (50,72) to assess dietary intake. No study, however, has used a semi-quantitative food frequency questionnaire covering the overall general dietary intake of the study population, although a food frequency questionnaire with limited selected food items has been used (23). The underlying principle of the food frequency approach is that average long term diet is the conceptually important exposure rather than intake on a few specific days (307). This is particularly important when studying the relationship between diet and dental health as caries develops over a period of time and caries incidence is dependent on long term dietary intake rather than present intake.

Sugar intake has been the most common nutrient researched with regard to dental health and thus two questions concerning sugar intake arise: As interest is now focussed on other nutrients besides sugar and diet as a whole, does a high sugar intake cause a deleterious imbalance or dilution of macro- and micronutrients and does it promote degenerative diseases, in particular dental caries? The Coma Report (308) concluded that on average people with high total energy intake eat more of all the nutrients, including sugars, and sugar intake is a weaker predictor of absolute micronutrient intakes than total energy consumptions. There have been several important contributions in this field. Rugg-Gunn *et al.* (309) examined the relationship between the intake of added sugars and other nutrients by analysing the diet of 405 English children aged 11-14-years. The nutrient intake of the subjects with the highest intake of added sugars in proportion to energy intake was compared with the nutrient intake of the subjects with the lowest intake of added sugar. Those eating the highest amount of added sugar consumed less protein and vitamin D

compared with those who ate the lowest amounts of added sugar. Non-significant trends were observed suggesting that those consuming diets containing low levels of added sugars in proportion to energy ate a more nutrient dense diet. However when nutrient intake was expressed as a g weight and not in proportion to energy, energy intake and consumption of most nutrients were considerably higher in those eating high levels of added sugars.

In the UK data files of 2705 school children surveyed in 1983 were reanalysed to provide an estimate of the total sugars and major sources of nutrients in the diets (180). Nutrient intakes were not significantly lower and indeed were often higher in those groups consuming most sugars. Energy intake appeared to be the major influence of intakes of nutrients. There was however a significant inverse relationship between sugars and percentage of energy from fat. Broadly it appears that a high sugar intake per se does not significantly nor disadvantageously reduce intakes of macro- and micronutrients. Furthermore a high sugar intake is associated with a lower percentage of energy from fat.

The Coma Report (308) also concluded that extensive evidence suggests that sugars are the most important dietary factor in the cause of dental caries. Recent research indicates that susceptibility to dental caries is little related to the reported intake of cariogenic food (310). Consequently there is need to focus dietary and other preventive efforts upon individuals and groups at high risk to dental caries. In children in a community about 80% of the caries occurs in 20% of the children (201,311,312)

Diet, in particular sugar intake in association with dental health has shown both significant

and non significant roles in caries incidence. Roeters *et al.* (72) found in every age interval statistically significant correlations between the daily number of food intakes and the number of sugar containing food ingestions, but reported low correlations between the diet scores and dmfs scores. Other studies in Dunedin (22), South America (313) as well as in South Africa (54,55) have also shown no significant associations between the intake of sugar, refined carbohydrate and dental caries incidence among preschool children. The importance of diet in caries incidence has, however, been demonstrated in other studies (23,66,69,314).

Some of the first reports to question the direct relationship between sugars intake and caries experience in the modern era came from Sweden, (280,315,316) and recent reports have confirmed these earlier findings of weak relationships, at best, between caries experienxce and various measures of sugar intake (209,278,317,318). Burt and Szpunar (70) used data from the Michigan Study (1982-1985) which collected detailed dietary information and caries incidence over a 3 year period on children aged 10-15-years. Results showed that caries incidence was poorly related to sugars intake, whether measured as total daily amount, between meal intake, sugars as a proportion of total energy, or frequency of consumption. They concluded that the principle reason for the low relative risk of caries development in the high sugar consumers was that with a small variance found with the patterns of both diet and caries, a substantial increase in either the number of participants or the length of the study would have been required for clearer relationships to emerge. The Michigan study used a 24-hour recall to assess the childrens dietary intake in relation to caries incidence, which cannot be taken as their usual intake. Only one day is recorded,

which may be atypical, in an attempt to measure caries incidence which develops over an extended period of time when diet may change quite considerably. This makes it hard to argue that the intakes of sugars is directly related to caries incidence in this population at least over a period of 3 years. The food frequency questionnaire used in the BTT study assessed nutrient intake over a longer period of time than the 24-hour recall and is therefore more related to usual intake. The results too, however, confirmed no direct or very weak relationship between sugars intake and dental caries incidence.

It should be noted that the correlation between diet and caries prevalence will be low when caries prevalence is low and the difference in diet habits is small. In South Africa dental caries in 5-year-old children from the Indian community showed an irregular trend towards increased caries with increasing amount and frequency of sucrose intake, but this was inconsistent and statistically not significant (319). Other cross-sectional data showed sugar consumption between 1976 and 1984 to remain relatively constant, 63-70g/day, among 5-year-old urban black South African children, but dental caries prevalence to worsen during this time as did the mean dmft scores (48,51,319,320). This was however in keeping with world wide trends that dental caries was reducing in developed populations and increasing in developing populations. By the 1990's the situation among the urban black community had changed. Sugar intake, although assessed by different assessment methods, had increased to about 78g/day by 1995 in the BTT study, but caries prevalence had decreased with approximately 60% of the 5-year-old urban black children having caries compared to approximately 70% between 1976 and 1978 and 78% in 1984 (319). In countries throughout Africa where the overall caries experience amongst children is rather low (321)

there are very few good studies on the relationship between diet, sugar and dental caries, but very low DMFT scores in the presence of moderately high sugar intakes have been noted in South Africa (322) and elsewhere in Africa. In northern Nigeria children who reported a remarkable level of consumption of sweets and sweet foods had low DMFT scores (323) and in Lagos, Nigeria the excellence of the teeth of the young was noted despite a 27 fold rise in sugar consumption (324).

Even meticulous analysis of dietary habits and food composition have not been able to explain within population variation in caries experience within children from the black community (276).

However, some recent studies have also found a more direct relationship between sugar and caries, though mostly in groups exposed to special hazards or in susceptible sub-groups within larger populations (325,326). Perhaps the data most similar to those reported from earlier generations comes from Iceland, where strong relationships between caries incidence and intakes of sugars have been reported (327,328). A high daily intake of sugars or retentive starch-sugar combinations has been correlated with a high caries experience in preschool and school-age children in three recent studies (201,329,330).

It is clear from the sugar controversy that convincing evidence is lacking that high intakes of sugar are detrimental to intakes of macro- and micronutrients and that sugar is a factor of less overriding importance in the development of dental caries than was previously thought. It is of course disappointing that the level of sugar intake explains so little of caries variance

and that the magnitude of the roles of the other influencing factors discussed remain unclear. None would doubt though that the known risk factors are important and have to be taken into account in programmes designed for the prevention or amelioration of dental caries. It is imperative to learn more of the markers which will detect the small proportion of children who are sensitive to sugar. Equally, endeavours should be made to secure more definite information as to what exactly child populations have been doing right to cause the huge and unexpected falls in caries occurrence during the last two decades. Perhaps much could be learned from intensive characterisation of those children with very low caries scores.

Since difference in intakes of sugar and sugar containing foods alone cannot explain the contrast in dental caries shown in South African populations and others mentioned, it would seem desirable to investigate possible roles of additional dietary components. Sognaes (64) for instance, attributed the war time caries improvements not so much to the depletion of sugar and sugar containing foods, but rather to the addition of fibre containing foods. The BTT study however only showed that by including fibre as a predictor of caries increased the significance of total fat as a predictor when a stepwise regression analysis on quartiles of nutrients was performed (results available but not shown). Increasing fat and decreasing fibre increased caries predictability. The predictor of caries by fat and fibre was, however, not strong in the BTT study.

Comparing the dietary habits of 15-year-old Swedish adolescents with high and low dental caries prevalence it was found that the group with nine or more decayed or filled surfaces

had worse dietary habits expressed as a higher fat intake, lower intake of complex carbohydrate and lower density of iron than the group with no dental caries. However, no difference was found in the sucrose intake between the two groups (317). Conversely, diets high in fat have been reported to be cariostatic (66) with the fat content of the diet lessening the caries producing aspects of cariogenic diets. In another study (289) analyses of three independent variables, percentage of energy from protein, fat and carbohydrate, against dmfs score resulted in only percentage of energy from fat being significant, explaining 9% of the variance in dmfs score for preschool children aged 3-5-years. Data on food consumption collected from rural and urban Tanzanians aged 12-74-years (331) suggested that subclinical protein-energy malnutrition was prevalent in Tanzania and that the high intakes of sucrose and cholesterol and low intake of fibre by the urban subjects could increase the prevalence of dental caries and cardiovascular disease in that population.

The BTT Study showed energy to be significantly related to caries incidence and prevalence, but this was possibly due to the effect of other nutrients as energy intake depends on the intake of separate nutrients, such as protein, fat, cholesterol and total available carbohydrate which significantly influenced dental caries incidence among the BTT children. However, other studies (31,62,223) one in Southern Africa, (62) have shown energy intake not to be related to caries.

b) Micronutrient intake

Regarding micronutrient intake, the few studies that have been carried out have shown contrasting results. The nutrient intakes of caries-free and caries active children, 3-4-years,

living in Dunedin, New Zealand were studied longitudinally over a period of 12 months. The 24-hour recall showed no significant differences in the mean intake of any nutrient between children who remained caries-free and those that developed caries (22). Marques and Messer (34) investigated the role of specific nutrients in the caries experience of preschool children aged 2-6-years. The average daily intake of 15 nutrients, protein, calcium, phosphorus, iron, magnesium, zinc , thiamin, riboflavin, nicotinic acid, vitamins A, B6, B12, D, folic acid and ascorbic acid, were computed and compared with RDA. Total sugar consumption and Ca/P ratio were also calculated. The intake of total sugar was not associated with high caries and, apart from a positive association with iron and a negative association with magnesium, caries was too not observed to be associated with any specific nutrient or Ca/P ratio. However, subsequent analysis indicated that these associations were the result of a significantly lower intake of iron and higher intake of magnesium by the younger age group of children. In contrast to Marques and Messer's study (34), Stacey (289) investigated the diet and feeding patterns in high risk preschool children 3-5-years of age. Stepwise multiple regression analyses of the daily intakes of 23 nutrients against caries experience (dmfs score) resulted in phosphorus and calcium being significant which together explained 17.7% of the variance in dmfs. Calcium and phosphorus are found in high concentrations in dairy products such as milk, yoghurt and cheese, and depending on the type of preparation, these products also contain a high percentage of fat. Phosphorus is also found in high concentrations in protein containing foods such as meat and eggs. This therefore suggests that children whose diets contain large amounts of dairy products have a lower caries experience than children whose diets are low in these foods (289). Findings by Reynolds and Johnson (332) and Weiss and Bibby (333) support these results. Other

research also supports the cariostatic effects of diets high in phosphates (334-336).

In a previous study 5, 9 and 13-year-old children with high and low caries experience were compared with regard to food and nutrient intake per 1000kcal. The intakes of most foods and nutrients were similar in both the high and low caries groups. However, the diet of the high caries group of 5-year-olds contained less iron, thiamin and ascorbic acid than the diet of the low caries group (337) .

The BTT Study too showed calcium and riboflavin to be significantly related to caries prevalence in the whole and riboflavin in both the whole and longitudinal group of children. Neither phosphorus nor iron showed any significant relationship to dental caries. Including social factors in the model did result in thiamin significantly influencing caries prevalence among the whole group of urban black children. In addition to these common nutrients found with the studies mentioned the BTT Study showed only ascorbic acid to be significantly related to caries incidence and magnesium, vitamins B12, A, B6 , E and biotin to significantly influence caries prevalence.

In the BTT study the excellence of the teeth of the 5-year-old children prevailed despite the intake of many of the essential nutrients being below the RDA, with also a large percentage of children falling below the RDA for many of the nutrients. This observation is at variance with views expressed by Nizel (200), Shaw (217) and others who aver that consumption of diets high in protein, calcium, certain vitamins etc. promote development of teeth less susceptible to caries.

CHAPTER 5.

THE IMPACT OF PAST DIETARY INTAKE AT 1-YEAR WITH THE DENTAL HEALTH AT 5-YEARS AMONG THE SAME CHILDREN

5.1 Introduction

Scores such as dmfs and dmft reflect the cumulative nature of dental caries. Attempts to correlate dietary information and caries scores are influenced by the age of the subject and the period of time for which teeth have been erupted. Therefore associations should be more readily apparent in younger individuals in whom there has been little change in dietary patterns over time.

Weaning practice can have a major influence on both the immediate and future dental health and good dietary practices from birth have the potential to secure a healthy dentition for life (293). It has, however, been shown that breastfeeding per se does not cause dental caries but rather the other promoting factors of poor oral hygiene or the intake (frequency and amount) of caries risk food items that co-exist (338). Most of the studies (56,284,314,338,339) relating present dental health with past dietary intake have discussed individual food items, particular sugar intake. No studies, however, have examined past energy, macro- or micronutrient intake with regard to present dental health among the same children. The BTT study thus provided an ideal opportunity to examine this relationship.

5.2. Methods

Subjects for this analysis included the whole longitudinal group [n=300] as well as children with caries only within this longitudinal group [n=184].

A computer programme was adapted to read the energy, macro- and micronutrient intake data at 1-year with the dental data at 5-years for the same individual in the true longitudinal group [n=300] .

As with the previous analyses, including social class and education level showed no significant relationship to dental caries at 5-years with nutrient intake at 1-year, and therefore they were not included in further analyses and are not reported in this chapter..

5.2.1 The Mantel-Haenszel x^2 test

Energy and each nutrient variable were divided into quartiles and thirds and dmfs scores were categorised into 3 classifications [dk(=0 or >0); dk2(=0,1-4,>5) and dk3(=0,1-4,5-9,>10)] explained in chapter 4, section 4.2.2.1. The Mantel Haenszel x^2 test for trend was carried out on each nutrient in quartiles and thirds.

5.2.2 Regression analysis

Regression analysis was carried out on dmfs and transformations of log(dmfs) and log (dmfs+0.3) for children in the whole true longitudinal group [n=300] and for individuals within this group that had caries only [n=184]. Energy and all the nutrients were included as independent variables. As with the previous analysis only the results of this transformation

will be reported in chapter 5 as this seemed to be the most appropriate selection with rationale behind its choice. Results of the other analyses are available.

5.3 Results

The Mantel Haenszel x^2 test for trend for macro- or micronutrient intake divided into quartiles or thirds showed no association with nutrient intake at 1-year to caries incidence at 5-years among the same children. (Results not shown as there was no association found)

Regression analysis tested if any macro- or micronutrient intake at 1-year could influence the incidence of caries at 5-years in the same children. This analysis of all nutrients against log(dmfs+0.3) showed no macronutrient to be related to the incidence of dental caries at 5-years in either the whole longitudinal group or the group with caries only (Table 5.1). Among the micronutrients potassium ($P<0.050$) and vitamin B6 ($P<0.010$) intake at 1-year in the whole longitudinal group was found to be associated with caries incidence at 5-years (Table 5.2). Social class and education level clearly showed no association on caries incidence and were thus not included in the analyses.

No association of nutrient intakes with caries incidence or prevalence at 5-years was found, therefore no further analysis was done.

Table 5.1 Regression analysis for all true longitudinal subjects and subjects with caries (dmfs>0) for all nutrient variables at 1-year against log(dmfs+0.3) at 5-years

I. macronutrients

	longitudinal group n=300		caries group n=184	
variable	parameter estimate	P value	parameter estimate	P value
energy	-0.011	0.643	-0.006	0.714
protein	0.134	0.232	0.049	0.539
fat	0.089	0.684	0.050	0.736
cholesterol	-0.001	0.766	-0.004	0.308
total available carbohydrate	0.052	0.595	0.010	0.879
fibre	0.089	0.463	0.033	0.675
added sugar	0.000	0.988	0.020	0.153

* = statistically significant (P<0.05)

Table 5.2 Regression analysis for all true longitudinal subjects and subjects with caries (dmfs>0) for all nutrient variables at 1-year against log(dmfs+0.3) at 5-years

II. micronutrients

	longitudinal group n=300		caries group n=184	
variable	parameter estimate	P value	parameter estimate	P value
calcium	0.002	0.598	-0.001	0.719
vitamin B12	-0.131	0.636	-0.139	0.441
iron	-0.104	0.505	0.011	0.924
magnesium	-0.004	0.800	0.002	0.891
phosphorus	0.000	0.988	0.001	0.833
potassium	-0.003	0.050*	0.001	0.443
sodium	-0.001	0.275	-0.000	0.703
zinc	-0.298	0.287	0.087	0.659
copper	0.214	0.908	-0.574	0.678
vitamin A (RE)	0.001	0.166	0.000	0.887
thiamin	-0.204	0.895	-0.563	0.582
riboflavin	-0.229	0.797	0.061	0.905
nicotinic acid	-0.037	0.841	-0.071	0.601
vitamin B6	2.310	0.010*	0.706	0.226
folic acid	-0.002	0.829	0.013	0.073
ascorbic acid	0.006	0.461	0.003	0.542
pantothenic acid	0.347	0.518	0.190	0.583
biotin	0.019	0.817	0.058	0.301
vitamin D	-0.000	0.995	-0.052	0.555
vitamin E	0.010	0.895	-0.047	0.437
manganese	-0.292	0.758	-0.396	0.574

*statistically significant (P<0.05)

5.4 Discussion

5.4.1 Main findings

The BTT study showed no intake of macronutrients at 1-year to be associated with caries incidence at 5-years among the same children and for the micronutrients analysing all nutrient variables against log(dmfs+0.3) showed only potassium and vitamin B6 intake at 1-year to be associated with caries incidence at 5-years in the whole longitudinal group. Again this association was isolated and is therefore not clinically relevant, being mathematical.

5.4.2 Breastfeeding and weaning in relation to dental caries

Breastfeeding was not included in the nutritional assessment of the 1-year-old BTT children but formed part of a separate research sub-group within the main study and was performed by other researchers. Results are not available for inclusion in this thesis. A study among South African children 1-4-years with the patterns of breast and bottle feeding and their associations with dental caries concluded that the method of infant feeding was not related to caries prevalence, but for those children affected by caries the amount of decay present was statistically significantly related to feeding method, dmfs and dmft being highest in the bottle fed group and lowest in the breast fed group. The caries prevalence increased with age more in the bottle fed children. The dmfs and dmft showed irregular patterns and were significantly influenced by feeding group and the interaction between race and social class. This conclusion only applied to those children who suffered with caries (60). A more recent study on the association between caries prevalence and dietary variables among 1.5 to 2.5-year-old Brazilian children (340) supported Roberts *et al.* (60) earlier results among South

African children.

Other studies on breastfeeding among South African communities by the Dental Research Institute of the University of the Witwatersrand have shown the frequency and number of children breastfeeding was highest among the black comm ty, particularly the rural blacks (58,61). More than 90% of the children in the black community tended to be breastfed and for a longer period of time than the other communities. Roberts *et al.* (60) found that 64-70% of the rural and urban black children were still being breastfed at 1-year . The prevalence and [mean daily frequency] of breastfeeding for the urban black children was 92.3%[5.5]. Information on the frequency of breastfeeding among the urban black BTT children at 1-year was very similar, being 94%, with 62% still receiving breast milk at 1-year (341).

5.4.3 Relationship of early dietary habits to present dental health

Wendt *et al.* investigated whether oral hygiene and dietary habits established at 1-year of age were maintained at 2-years of age and analysed caries related factors with regard to oral health between the age of 1- and 3- years using a salutogenic theory - that is focussing on behavioural factors that do not result in impairment of health. Caries related habits established during infancy were found to be maintained throughout childhood (338) and confirmed earlier findings (56,339) that it was not the breastfeeding per se that causes dental caries but rather the other caries promoting factors like poor oral hygiene, or intake of sugar containing liquid when thirsty that co-existed in these children (338). All the children who had received sugar containing liquid during the night at 1-year of age had

developed caries at 3-years of age. This possibly confirms that if breastfeeding had been included in the nutritional analysis of the 1-year-old it would have had little effect on incidence of dental caries at 5-years.

Wendt's *et al.* (339) earlier study found that Swedish children with caries at 2- and 3-years of age had when they were 1-year-old consumed caries risk products and had been given nocturnal meals and sweetened liquid in a feeding bottles more often than caries free 2- and 3- year-olds. The change in consumption of caries-risk products during infancy was illustrated by the fact that sweets were consumed at least once a week by 31% of the 1-year-olds and by 80% of the 2-year-olds. At 1-year of age 49% of the children had a total intake of caries-risk products exceeding once a day, compared with 89% of the 2-year-olds. The study showed that differences in dietary habits at 1-year existed between children who developed caries at the age of 3-years and children who had not. This is in agreement with the findings of Persson *et al.* (294) who found that 3-year-olds with caries had consumed cakes, soft drinks and sweets more frequently at the age of 1-year than 3-year-olds without caries and Grytten *et al.* (342) who showed that the frequency of sugar consumption at 18 months was significantly related to caries experience at 36 months.

In studies on the prediction of caries in preschool children, intake frequency, amount of sugar, misuse of sugar, or daily intake of caries-risk products has been used as a dietary habit index (314,343,344). In Wendt's (338) study almost all these dietary variables at 1-year differed significantly between children who had developed carious lesions at the age of 3-years and children who had not. This reflects the complexity of the diet with regard to

dental caries and the difficulties in expressing dietary habits as a simple index and explains the contrast with the finding of the BTT study.

It has been shown that sugar intake increases from the age of 10 months to 2-years (345). Thus theoretically dietary intake at 1-year should have a greater impact of caries prevalence in 3-year-olds than the impact of dietary intake at 2-years on caries at 3-years. This was shown in Wendt's (338) study for individual caries-risk food items but not in the BTT study for the nutrients analysed. The BTT study, however, did not analyse specific food items and one can only surmise that the statement may have held true for specific food items. Sugar was the only common variable between Wendts study and the BTT with the latter study showing no significant effect of sugar intake at 1-year with caries incidence at 5-years.

Wendt's (338) study as well as the BTT Study were on a group level but Schroder *et al.* (343) showed that by studying the same factors there was no or only small possibilities of predicting caries on an individual level in the primary dentition at an early age. This is in accordance with studies in prediction of caries in older preschool children (314).

5.4.4 Conclusion

Energy, macro - and micronutrient intake of urban black South African children at 1-year showed no association with their dental health when they were 5-years. The published studies discussed have shown contrasting results, which suggest that actual food items consumed at an early age may be better predictors of future dental health than macro- or micronutrients.

CHAPTER 6.

DISCUSSION: METHODOLOGY CRITICISM AND OVERALL CONCLUSIONS

6.1 Assumptions in cohort studies.

To study how diet or change in diet affects the risk of developing a disease or condition requires the following assumptions:

1. diet and outcome/exposures remain constant between periods of assessment or

2. changes in diet affect all subjects similarly so that rank order is not affected or

3. changes in diet are sufficiently near in time to the occurrence of the disease under study that they cannot influence the outcome or

4. changes in diet cannot affect the development of diseases.

It is usually assumed that the disease was not present when the diet was originally assessed or that it did not affect dietary intake at that time. These assumptions, however, do not apply to periodic cross-sectional studies. The point that may be difficult to assess is not whether the assumptions hold true for the particular study in question but the degree to which they are violated. These violations are, however, not so severe as to invalidate the study (114).

6.2 Issues in the selection of a dietary survey methodology

The focus of studies in nutritional epidemiology is primarily on the relationship between an individual's "usual", representative intake and the risk of disease (346-348). This is particularly important when studying the relationship between diet and dental health as caries develops over a period of time and caries incidence is dependent on long term dietary

intake rather than present intake. The most controversial aspect of these studies is the selection of the dietary survey methodology (307,349). It is true that there is no gold standard method for measuring dietary intake as all contain measurement error (114), and all dietary survey methods have their limitations, which one must be aware of in selecting the particular method (307). The choice must thus be based on simplicity and assessed relative validity (350).

"Nutrition and dental caries in Africa" (2) emphasizes the difficulty of considering nutrition information in relation to dental caries in an African country. Researchers must choose not only what type of information they wish to collect but also the methodology for doing this.

Usually the only practical methods to choose from for large studies are 24-hour recalls, hand written food records, food records using precoded or list-based forms and food frequency questionnaires that are also precoded or list-based. In principle any of these methods mentioned could be used in nutritional studies (114).

However, many problems have been noted with daily food records and 24-hour recalls (88,348,349,351). The fact that a single days recording is not representative of usual intake, due to a large amount of within person variation, and that these methods are costly are the two most important reasons cited for why they are inappropriate for epidemiological studies (88,114,348,352). The choice must, however, be based on the design and objective of the study and on the level of information required (114).

When assessing the level of information required two aspects must be considered. First, is the objective of the study to assess the relative ranking of each individuals usual intake? Second, is the objective of the study to estimate the intake of broad classes of foods, nutrient intake or other more complex aspects of the diet related to the absorption, utilisation and metabolism of particular food constituents (114)?

Reliable, practical and valid measures of typical diet are needed for public health research. Dietary recalls may accurately estimate nutrient intakes, but large day to day variations in diet necessitate multiple labour intensive administrations to measure individuals typical intakes. Single administration of a food frequency questionnaire have yielded acceptably reliable and inexpensive estimates of typical intake for a range of nutrients in various contexts. Thus despite limitations, food frequency questionnaires have become the primary tool for dietary measurement in epidemiological studies, the semiquantitative type being the most common presently in use (348). The Willett group has conducted some of the most rigorous studies to evaluate the validity of this questionnaire and the group has been one of the leading proponents of the use of this methodology in epidemiological studies (307).

Although this questionnaire is a useful tool in epidemiological studies on nutrient intake and disease relationships, it is subject to substantial measurement error (350). However, moderate reproducibility of nutrient intake in general populations has been found by investigators (346,350). Three month and 1-year reproducibility of Latina mothers and childrens intake of energy and 11 nutrients yielded correlations between 0.4 and 0.55 for most nutrients (346). This study can possibly, to a limited extent, be extrapolated to the

BTT study as the children were the same age (5-years) and most were from low income families, although communities differed, but thus far no South African study has been conducted to determine the validity or reproducibility of the food frequency questionnaire among urban black preschool children . However, a recent study in the North West Province of South Africa showed the quantitative food frequency questionnaire to be reproducible and relatively valid for assessing the dietary intakes for the black population in this province (89). This has possibly been the most detailed study on dietary methodology ever undertaken in South Africa.

The food frequency questionnaire has also been found to be useful in describing the dietary habits in a given population and fundamentally when the population studied is to be classified according to the normal consumption of energy and macronutrients (353). Any discrepancies in findings with regard to the reproducibility of nutrients reported in different studies could be due to many factors including measurement error with inaccurate reporting, long term dietary changes at the individual level, diet variability between individuals and study design differences (350).

Food frequency questionnaires are usually precoded forms that consist of a few selected core foods which are grouped into food groups of similar nutrient composition (307). Each food item or group used on a precoded form, such as the one used in the BTT Study, has many variations which means that the nutrient composition for any one food group is the average of the composition for the items within the group (354,355). Because of the complex, varied and dynamic nutrient composition of the large number of available foods,

foods on precoded forms must be grouped on the basis of similar nutrient composition for the key nutrients or dietary factors of interest in order to decrease the measurement error of these nutrients (307). The precoded foods on the BTT questionnaire were grouped according to similar nutrient content, covering all the main South African food groups which would have reduced the measurement error. The trade-off, however, is less total information for more rapid data handling (354).

As time passes the core foods for the cohort can also change, as can the nutrient composition of the foods already present in the form. It is thus likely that the same questionnaire used repeatedly in a longitudinal cohort may become obsolete and need revision (307).

Food frequency questionnaires with listed food items do not have the ability to record information on food preparation methods, foods consumed together as meals and as mixed dishes, type of food, brand name, packaging, ingredients and the size of the individuals portions in the detail that could be taken from a 24-hour recall or food record (307,349).

Precoded food frequency questionnaires are not as flexible as hand written daily food records or 24-hour recalls (307,347,349,352). Some nutrients not selected for the study may be poorly estimated due to food grouping according to similar nutrient content (354on 1982). The design of our questionnaire was based on assessing the overall diet of 5-year-old urban black South African children and foods were not precoded for selected nutrients or a specific disease condition, thus the main macro- and micronutrients were most likely well

estimated, although there is a possibility that certain nutrients may have been poorly estimated.

With the food list containing a limited number of foods and foods being grouped together, the information yielded is not comparable to that from daily food records or 24-hour recalls (307,349,351). Accordingly, the questionnaire is appropriate to meet only limited and predefined objectives (307). The semiquantitative food frequency questionnaire met this study's objective of assessing the dietary intake of the selected population.

In culturally diverse populations, such as in South Africa, it may be impossible to develop a food list that is reasonably short while including all of the essential core foods eaten by the different ethnic groups (307). Foods important to the individuals diet may be omitted if they are not mentioned in the questionnaire (307). The food items listed in our questionnaire were based on many years of dietary assessment among South African children and analysis was based on group intake, not individual. It is therefore almost certain that the questionnaire covered most of the foods consumed by South African preschool children. The fact that group intake was analysed reduced both inter- and intra individual variation in nutrient intake to some extent.

Both nutritionists and epidemiologists recognise the fact that some loss of accuracy and precision in estimation of dietary intake is unavoidable in epidemiological studies. The problem comes in agreeing on what is an acceptable level of accuracy and precision. There is also the issue of how much flexibility can be sacrificed in order to reduce time and costs

(307). Large scale cohort studies, such as the BTT, are very costly and to maintain support for them they have to have flexibility (307,349). They need to be able to respond to dietary issues and questions which could not have been anticipated during the design of the study (307). Once again the fact that this study's questionnaire covered the overall diet of South African preschool children and was not aimed at any specific nutrient/s or disease condition will enable researchers to answer probable questions not anticipated during the study design.

Food frequency questionnaires tend to overestimate food intake (159,346,356), but the degree of overestimation depends on the number of food groups and food types in the questionnaire. Overestimation may also be partly accounted for by underestimation of usual intake by the comparison method, especially if weighed food records are used, since these often lead to disruption of usual dietary patterns (356).

It has been suggested that a combination of methods provides more useful information than a single method (160), but this is not practical in large scale studies such as those reported.

Multiple food records appear to be the standard method for estimating usual food intake in population groups (307). But, is it necessary to estimate absolute intake? Ranking is the primary objective of most epidemiological studies (348). It has also been said that the requirement for dietary surveys in epidemiological studies to estimate absolute levels of total intake may be unnecessary and unrealistic (88). The relatively low correlation coefficients in some published studies of the validity of food frequency questionnaires show

that relative ranking is not well preserved for certain nutrients (357-359). But even if this were so the data would not identify what specific intake levels confer increased risk on an individual or monitor changes in intake or evaluate effectively the prevalence of the population at highest risk. It must be noted that the validation of a food frequency questionnaire by comparison with another established and accepted approach characterises only the relative validity of the questionnaire with respect to the relevance method, not the absolute validity (356). A review of existing validation studies undertaken as a step in selecting appropriate methods have shown similar correlations between the semiquantitative food frequency questionnaire and the comparative method for fat intake using food models (360), household measures (357) and photographs (356) to estimate portion sizes.

For large cohort studies with the sample spread over a wide area, semi-quantitative food frequency questionnaires may thus be the most practical approach for estimating dietary intake (307). The general consensus, however, is that they should not be used to assess individual nutrient intake, but may be useful in estimating an individual's relative percentage of energy from nutrients, such as fat (356).

Although it is difficult to compare food frequency questionnaires due to different food list sizes and sources, frequency estimation, portion size estimation techniques, and sample characteristics from a review of the literature, it is felt that portion size estimation may be of use in these questionnaires if a suitable estimation method is used together with an appropriate length of food list. One of the most difficult aspects of the collection of dietary data, irrespective of the method used, is obtaining accurate information on the amounts of

food consumed. There is however some argument as to whether the estimation of portion sizes is necessary for the collection of dietary data using the food frequency questionnaire. In some instances the average portion sizes have shown only slight improvements in correlations in nutrient intakes when food frequency questionnaires with and without portion size estimation were compared with diet records (361,362). As portion sizes vary less among individuals than do frequencies of intake, some researchers believe that the frequency of intake is sufficient to give information on dietary intakes of a population (348). The fact that the BTT study used standardised portions must have resulted in some inaccuracy in nutrient intake on an individual level but on a group basis this was avoided to a large extent, with the emphasis on the data being only an estimate of actual intake.

6.2.1 Summary of errors specific to food frequency questionnaires

As a result of their structure food frequency questionnaires may give rise to other errors. Factors that may contribute to errors are the following:

i. Since the food frequency questionnaire is based on a preset list of foods, omissions of foods from the food list may result in underestimation of intakes (307).

ii. Grouping of foods together into groups may result in the loss of information concerning preparation methods and differences in the type of individual foods.(307).

iii. No information is given about foods consumed together as meals or mixed dishes and the sizes of individual portions (307).

iv Respondents have to remember all dishes which contain a given item, separate

mixed dishes into their component foods, estimate the amount they usually consume, add it together with other sources of the food and then estimate the frequency of consumption (307). This may result in subjects making inferences from the foods most easily estimated or simply guessing amounts and frequencies (363).

v. Semiquantitative food frequency questionnaires which make use of average portion sizes may result in over or underestimation depending on the difference between the average portion size and the actual amount of food consumed (364).

vi. Subjects may be unable to recall or aggregate all eating patterns of a month or a year accurately (364).

In view of the above criticism on this dietary assessment method, the underlying principle of the food frequency questionnaire approach being that average long term diet is the conceptually important issue rather than intake on a few specific days, its ease of application, cost effectiveness in large scale studies and the fact that current epidemiologic knowledge on diet and disease stimulates cohort studies using 7-day dietary records or semiquantitative food frequency questionnaires (365), made this, the semiquantitative food frequency questionnaire, the preferred method of choice (346,348,356).

One must always keep in mind though that dietary intake is only an estimate as there is no golden standard and dietary intake cannot be assessed without error and probably never will be.

6.3 Data collection procedures and nutrient data bases

The selection of an appropriate dietary data collection methodology does not eliminate all of the issues relative to long term evaluation of dietary intake for a population. Procedures for collecting and coding the data and the selection of an appropriate food composition data base to convert dietary data into nutrient intake are equally important for valid nutrient data. In studies of multicultural, multilingual populations, it is important to recognise that cultural factors and language can influence the way in which foods are reported by members of different ethnic groups (366). Some of the foods associated with an ethnic group may be frequently consumed by members of the larger population, although these foods may have been modified to be nutritionally different from the traditional ethnic version (367). To minimise biases of this kind, language and culture-specific foods references should be considered when selecting a dietary methodology to be used with a multicultural population. The expanded food list must also be flexible enough to reduce the chances of misinterpretation by the interviewer or subject. Errors resulting from misinterpretation due to language and culture-specific food references may affect the ability to evaluate dietary habits within and between ethnic subgroups and to detect changes in eating patterns over time within an ethnic group.

Complete accurate and reliable food composition data are essential (347,368-370) Important criteria for selecting an appropriate food composition data base include 1. comprehensiveness of the data base with respect to foods and nutrients to address multiple data uses. 2. completeness of the data base for nutrient values based on reliable sources. 3. stability for continuous or long term data collection but with flexibility to expand, adapt and

record time specific information and updates and suitability for the study population.

Nutrient data for foods consumed principally by specific ethnic groups may be unavailable or inappropriate (367). Alternative strategies for finding food composition data include substituting nutrient data for similar foods. This could introduce error in studies that focus on the diets of particular ethnic subgroups or subgroup comparisons (367). The lack of appropriate nutrient data may make it difficult to detect similarities or differences between members of specific ethnic groups and the general population.

Increasing diversity of foods available in the marketplace contribute to the need for a rapidly changing data base.

Changes and improvements to the food composition data base due to better analytic information need to be distinguished from real changes in dietary intake over time (371,372). For time trend analysis of dietary intake data from longitudinal studies as well as from cohort studies with repeated dietary measurement it is essential to determine whether the observed changes reflect real changes on dietary intake or if they are due to differences in food composition data bases or coding procedures.

Time related data bases that permit comparison of food and nutrient intakes over time are essential for nutrition monitoring as well as for long term studies investigating diet/health relationships (371-373).

6.4 Data analysis issues

The longitudinal analysis of dietary data requires the consideration of both statistical and biological issues. Two issues that are of importance in the analysis of dietary data are measurement error and misclassification in nutrient intake.

When nutrient intake is measured with error, some subjects are likely to be misclassified into the wrong group when they are classified into quartiles of nutrient intake. This misclassification can be quite substantial depending on the dietary assessment method used and the specific nutrient of interest. The degree and direction of bias can vary according to whether the misclassification of nutrient intake is different for persons with the disease than for persons without (differential) or the same for person with or without the disease (non-differential). Research has shown that when exposure categories are formed from dietary data or other continuous measurement, misclassification is likely to be differential even in cohort studies (114).

6.5 Energy adjustment

Another complex issue that has generated much discussion is whether or how nutrient intake data should be adjusted for total energy intake (209,348,370,374-377). Macronutrients have often been expressed in terms of their percentage contribution to total energy intake, whereas vitamins and minerals have been expressed in units per 1000 kcal.

The issue has its basis in the fact that nutrient intake is highly correlated with energy intake and there is a great deal of intercorrelation in nutrient intake that makes it difficult to assess

the role of a particular nutrient in the disease etiology taking into account the intake of other nutrients (347,370,378). People with higher energy intakes will also tend to consume more of most nutrients and this alone may lead to the finding of spurious association with the intake of a particular nutrient.

Another reason to calculate energy adjusted vitamin and mineral intake appears to be the variability in measurement error in energy intake estimates with food frequency questionnaires, in particular. To the extent that measurement error is similar for all foods for an individual, nutrient intake relative to energy intake will be measured more accurately than absolute nutrient intake.

For dietary assessment methods that measure total intake with similar accuracy across individuals, unadjusted intake of most nutrients, particularly vitamins and minerals, is likely to be more biologically meaningful than energy adjusted intake. Unfortunately there is rarely a biological basis available for choosing between adjusted and unadjusted values and the different models for adjusting for energy intake have different biological interpretations (375-377).

Some nutrient estimates are by their nature very skewed, for example copper, iron, zinc, vitamin A, vitamin B12, and vitamin E. This is due to the variability of food intake from day to day and thus for non normally distributed variables the means and standard errors of the means which assume normality should be used and interpreted with caution (103).

Unadjusted nutrient intake was chosen to calculate the nutrient intake in the BTT study for formality with other studies on diet and caries.

6.6 Dental caries methodology

Recently Burt (379) reviewed the uses of surveys and some of the issues involved in measuring dental caries in them. The principle benefits of these surveys are in monitoring trends in oral disease when the surveys are repeated periodically and giving dental health a visibility it might otherwise not get among policy makers. However, surveys have limited use without other data for comparison, in determining treatment needs for a population, evaluating treatment outcomes, and evaluating prevention programmes. Some major issues in caries surveys today include difficulties with DMF index, the use of exclusively visual versus visual-tactile criteria, "hidden" caries and the appropriate role for early, non-cavitated carious lesions (379)

The DMF, which also refers to the dmf in the primary dentition, index, has been so versatile for studying caries that it has been extensively and widely used, with very little challenge over the past 50 years (380). It is almost 60 years since Klein *et al.* (381) described this index as a measure of cumulative caries experience of the permanent teeth of children. Most criticism of this index is the handling of the missing teeth or its distortion through treatment services. However there are increasing references to its shortcomings in the new era of caries (382).

Stamm (383), for instance, stated that the decline in caries experience and large numbers of

children who do not develop new lesions was making the problem of optimal outcome measurement more urgent in clinical trials. O'Mullane (384) stated that while DMF index scores may have been reasonable when caries levels were higher it would seem an inefficient method of using information on the progression of caries. Issues prompting the reassessment of the epidemiology of caries are the apparent decline in prevalence and incidence of caries and the accompanying skewness of data from studies on caries in children from industrialised and deprived countries (382).

Existing DMF index data on caries prevalence and incidence in children leaves something to be desired. They fall short of satisfying well the constitutive interests for which they have been collected in the range of epidemiological studies of caries. A number of factors contribute to this situation. First, there is a narrowness to the type of caries epidemiology conducted so that the full range of constitutive interests is not always recognised. Second, there is a lack of conceptual rigour applied to planning studies so that the collected data will achieve the desired aims. Third, there is a covert pressure to stay with the traditional measure, the DMF index (382). Traditional DMF index data does, however, underestimate the prevalence of caries today and overestimate temporal change, have limitations in segmenting the populations in the most useful ways for targeting as part of policy development and lack discrimination between individuals with different caries activity. There has thus been an increasing reliance on not just the mean DMF index scores, but also the distribution of the DMF index scores (382).

Another limitation of the DMF index is that it carries the assumption that all filled teeth

were carious prior to the filling, but there is now evidence to show that the variation in dentists treatment decisions leads to the "F" component of the DMF score overestimating caries experience (385). Under any circumstances survey results underestimate the true situation, some lesions will always be missed because examination conditions are less than ideal. Other deficiencies of the index include the absence of a denominator which means that DMF values need to be presented in age related form to have much meaning. However, there are advantages of using the DMF index. It is conceptually simple, can be modified for particular circumstances and has been widely accepted for many years and is likely to be the basis for caries measurement for some time yet (379).

Spencer *et al.* (382) examined the possible consequences of the highly positively skewed caries data emerging from many studies among young children, partly due to the diagnostic threshold of the cavitated lesion. There has been an understandable historical rationale for counting only cavitated lesions mainly for improved reproducibility. This has over-ridden the desire for absolute correctness of observation on the caries process (382).

It should be remembered that these traditional criteria for measuring caries were established at a time when knowledge of the natural history of the caries was limited. There have been many advances since then, the principle one being that we now understand the reversibility of the early carious lesion. Better knowledge of caries dynamics has changed the approach to preventative and restorative dentistry and caries is recognised as a disease that can progress throughout life (321). Treatment needs can only be assessed in very broad terms because there is a clear gap between the criteria used in surveys and those applied by

dentists (386).

The varied anatomy of epidemiological studies of caries now requires new caries outcome measures that conceptually reflect the constitutive interests and circumstances of the studies in which they are used and practical recognition of the nature and distribution of the outcome measures available (382). It is suggested that these new outcome measures for caries should include caries severity grading with diagnosing, recording and analysis of one or more grade of non-cavitated enamel lesions, development of prevalence, extent and severity measures which can be combined into case definitions with binary outcomes and weighted indices and utility functions that reflect the quality of oral health enjoyed by an individual (382). A number of other researchers have also stated that non cavitated lesions should now be included in surveys (387,388). However the situation is not so clear cut. In some instances the inclusion would enhance the value of the data, while in others the additional cost would not be offset by the additional benefits (379). There is thus a need for further research on the use of exclusively visual criteria rather than the traditional visual-tactile criteria to determine their appropriateness for surveys. Trade-offs such as weighing the benefits of exclusively visual criteria against the probable greater difficulty in "hidden" caries have not yet been determined (379).

It is clear though that the dental findings of the BTT study are subject to several limitations associated with the nature of survey examination . First, for ethical reasons, the oral examination did not include radiographs to detect interproximal caries, thus the amount of caries must underestimate the true prevalence. This is balanced to some degree because the

criteria used for survey diagnosis are stricter than clinical criteria for treatment in clinical practice. However these limitations related to the examination protocol did not bias the results as they applied to all children examined.

6.7 Overall conclusions

The overall objective of this study was to investigate the relationships between dietary intake, macronutrient and micronutrient intake and dental health among 5-year-old urban black South African children in a longitudinal cohort, through six specific objectives: These are listed below together with their relevant conclusions.

1. To compare the energy, macronutrient and micronutrient intake of 5-year-old urban black South African children in 1984 and 1995. This was to determine if the dietary intake of 5-year-old urban black South African children has changed over the past decade.

The study indeed showed that, together with the changes that have taken place in South Africa, the dietary intake of 5-year-old urban black children living in the Gauteng Province of South Africa has changed over the past decade. The consumption of a diet high in carbohydrate and low in fat (Prudent diet) in 1984 had changed to a typical westernised diet high in fat and low in carbohydrate by 1995, with the fat intake almost doubling over this time. The diet increased quantitatively but decreased qualitatively from 1984 to 1995 as the intake of many nutrients were still below the RDA in 1995.

2. To compare the energy, macronutrient and micronutrient intake of 5-year-old urban black South African children who had dietary information in 1991 and in 1995 to those who had dietary information for only 1991 or only 1995. This determined if there was a difference between those individuals who were in the nutrition cohort and those who were not.

3. To compare the energy, macronutrient and micronutrient intake of 5-year-old urban black South African children who had dietary information for 1991 and 1995 as well as dental information for 1995 to those who had only dietary information for 1991 and 1995. This determined if those individuals who had dietary information for 1991 and 1995 as well as dental information for 1995 differed from those who had only dietary information for the two interceptions.

Regarding objectives 2 and 3: The children that had nutrition information for 1991 and 1995 did not differ significantly from those who only had nutrition information for 1991 or 1995. Likewise, the individuals that had nutrition information for 1991 and 1995 as well as dental information for 1995 did not differ significantly from those who only had dietary information for the two interceptions. Therefore the study samples were representative of 5-year-old urban black children within the Birth-to-Ten cohort.

4. To study the relationship between energy, macronutrient and micronutrient intake and dental caries among 5-year-old urban black South African children, in particular, to determine if any dietary factors could be risk markers for caries in the future.

The association of any macro- and/or micronutrient with the prevalence and/or incidence of dental caries was weak, isolated and mathematical - of no clinical relevance. It is clear that energy, macro- or micronutrients are not risk markers for caries incidence among 5-year-old urban black South African children.

5. To study the impact of past dietary intake at 1-year on the incidence of dental caries in the same individuals at 5-years among urban black South African children.

Energy, macro- and micronutrient intake at 1-year did not influence dental caries incidence at 5-years among the same urban black South African children. The association of the nutrients was weak and isolated and of no clinical relevance. The individual food items themselves may prove better predictors of future caries.

6. To determine, together with some dietary variables, the additional influence of some confounding variables (eg. social class, educational level) on the presence of dental caries among 5-year-old urban black South African children.

Including social class and parents education level in the analysis, together with the dietary variables, did not influence the incidence of dental caries among 5-year-old urban black South African children. These confounding factors however did not form a major part of the study.

This study was specific to 5-year-old urban black South African children and cannot be extrapolated to other age groups or communities. The diet as a whole including energy, macro- and micronutrient intake in relation to dental health was investigated. This is in contrast to studying only sugar and/or carbohydrates in the caries process. The study has emphasised the complex nature of the caries process. It has also provided unique information on the dietary intake, as a whole, together with the dental health in a

longitudinal cohort of representative South African preschool children.

6.8 Future research prospects

Research into nutrition is a neglected area in South African Health Sciences Faculties. Future research into nutritional aspects of disease, particularly those affecting children, should be expanded. With regard to dental caries similar sets of dietary evaluations in the older child ie. mixed dentition (12-year-olds) and in the young adult (15-19-year-olds) would be ideal. Hopefully, the Birth-to-Ten (BTT) study will continue to be followed as part of an extended study in the Department of Paediatrics (Chris Hani Baragwanath Hopspital), with which the author is associated.

APPENDIX A. DIETARY QUESTIONNAIRE 1984

NAME_____SEX____ REF.NO._____ SCHOOL_____
BIRTH DATE_____SURVEY DATE_____

Please indicate amount*, when and number of times you eat or drink each food item.

*Amount (use symbol in brackets)
grammes(g); cup(c);teaspoon(t); tablespoon(T); slice(s); portion(p)

FOOD ITEM	AMOUNT	WHEN EATEN		TIMES EATEN			
	g, c, t T, s, p	with meals	between meals	per day	per week	per month	seldom never
DRINKS:							
Tea:							
black/							
with milk							
sugar/cup(t)							
coffee:							
black/							
with milk							
sugar/cup(t)							
Milo/Choc:							
with milk/							
with water							
sugar/ glass(t)							
Milkshake							
Cooldrink:							
Coke/Fanta/Sprite							
Fruit squash:							
Oros							
fresh fruit juice:							
Liquifruit							
PORRIDGE:							
mieliemeal							
soft/sour							
Maltabella							
Oats/							
Tasteewht							
milk added (c)							
sugar added(t)							

FOOD ITEM	AMOUNT	WHEN EATEN		TIMES EATEN			
	g, c, t T, s, p	with meals	between meals	per day	per week	per month	seldom never
CEREAL							
Pronutro/							
Muesli/							
Cornflakes							
Weetbix/							
All Bran							
Sweetened:							
Coco-pops/							
Frosted Flakes							
milk added (c)							
sugar added (t)							
BREAD							
white/brown							
wholewheat							
Crispbread							
Provita/							
Cream cracker/							
SPREADS:							
butter							
margarine							
liver spread/							
fish paste/							
sandwich spread/							
peanut butter/							
Nutella/							
Marmite/							
jam/syrup/honey							
CAKES/ SNACKS/							
BISCUITS:							
cake:state							
tart:state							
scone/							
doughnut/ vetkoek/							
roti							
Pastry							
(sweet):							
Danish/ jam tart							
(savoury):							
sausage roll/							
samosas							
Biscuits:							
plain/ filled:							

FOOD ITEM	AMOUNT g, c, t T, s, p	WHEN EATEN with meals	WHEN EATEN between meals	TIMES EATEN per day	TIMES EATEN per week	TIMES EATEN per month	TIMES EATEN seldom never
Crisps:							
Simba/ Niknaks/							
Cheese curls							
popcorn:							
sweet/salt							
Nuts:							
peanuts/almonds/							
walnuts							
coconut							
SWEETS/ CHOC:							
(amount/ cost/g)							
candies/ sucker/							
stok							
sugus/gums							
jelly tots							
toffees/ fudge/							
caramel/							
nougat							
chocolate:							
plain/ filled/							
choc bars							
other: state							
china fruit etc.							
FRUIT							
FRESH:							
average							
apple							
apricot							
fig							
banana							
berries							
(state)							
grapefruit							
naartjie							
grapes							
guava							
mango							
melon							
(state)							
orange							
paw-paw							
pear							

FOOD ITEM	AMOUNT	WHEN EATEN		TIMES EATEN			
	g, c, t T, s, p	with meals	between meals	per day	per week	per month	seldom never
peach							
plum							
pineapple							
DRIED FRUIT:							
raisins/ sultanas/							
currants/							
prunes/							
dates/							
mixed (state)							
Glazed: cherries (state)							
PUDDINGS:							
fruit salad:							
fresh/tinned							
tinned fruit (state)							
pudding:							
baked/ steamed							
milk pudding:							
custard/							
instant/							
jelly							
other (state)							
MILK PRODUCTS:							
Fresh: full cream							
skimmed/							
sour(maas)							
buttermilk							
ultramel							
powdered							
evaporated							
condensed							
Yoghurt:							
plain/ fruit/							
yogisip							
Cheese:							
Gouda/ Cheddar/							
processed							
cottage/ creamed							
Cream:							
fresh/tnd							
Ice-cream: (state)							
Non-dairy creamers:							
Cremora							

FOOD ITEM	AMOUNT	WHEN EATEN		TIMES EATEN			
	g, c, t T, s, p	with meals	between meals	per day	per week	per month	seldom never
MEAT:							
beef							
mutton							
lamb							
pork/bacon							
ham							
liver/ kidney/ tripe							
sausage:							
vienna/							
boerewors/							
russians							
mince/stew/curries/							
pies							
cold processed							
meat (state)							
gravy							
meat extract							
POULTRY:							
chicken							
(state)							
Eggs:							
boiled/ fried/							
scrambled/poached/							
omelette							
FISH:							
hake/sole							
haddock/							
fish sticks/							
snoek/							
kipper/ herring							
Tinned:							
tuna/							
sardines/ pilchards							
FATS/OILS:							
cooking oil							
salad dressing							
mayonnaise							
lard/ dripping							
hard fats							

FOOD ITEM	AMOUNT g, c, t T, s, p	WHEN EATEN with meals	WHEN EATEN between meals	TIMES EATEN per day	TIMES EATEN per week	TIMES EATEN per month	TIMES EATEN seldom never
VEGETABLES							
raw:							
lettuce/ cucumber/							
pepper/ onion/							
tomatoes/							
carrots							
cooked:							
onion/ tomato							
Root:							
carrots/							
beetroot/							
turnip/							
Leafy:							
spinach/							
cabbage/							
morogo							
Flower:							
cauliflower/							
broccoli							
Squash:							
pumpkin/							
marrow/ gem squash							
Legumes:							
green peas							
beans							
(dried:)							
beans/peas/lentils							
sweetcorn/							
baked beans							
mixed veg							
brinjal/							
mushrooms							
asparagus							
avocado pear							
others							
(state)							
STARCH:							
potatoes:							
boiled/							
baked/							
mashed/							
salad/							
chips							

FOOD ITEM	AMOUNT	WHEN EATEN		TIMES EATEN			
	g, c, t T, s, p	with meals	between meals	per day	per week	per month	seldom never
jacket potatoes							
rice							
fresh mielies							
stiff m/meal							
m/rice							
samp							
pastas:							
spaghetti/macaroni/ noodles							
SOUP:							
(state)							
SAUCES:							
tomato/							
mustard/							
white sauce							
cheese sauce							
chutney/							
pickles/							
achaar							
other (state)							

FLUORIDE EXPOSURE

1. Do you use toothpaste? yes no sometimes

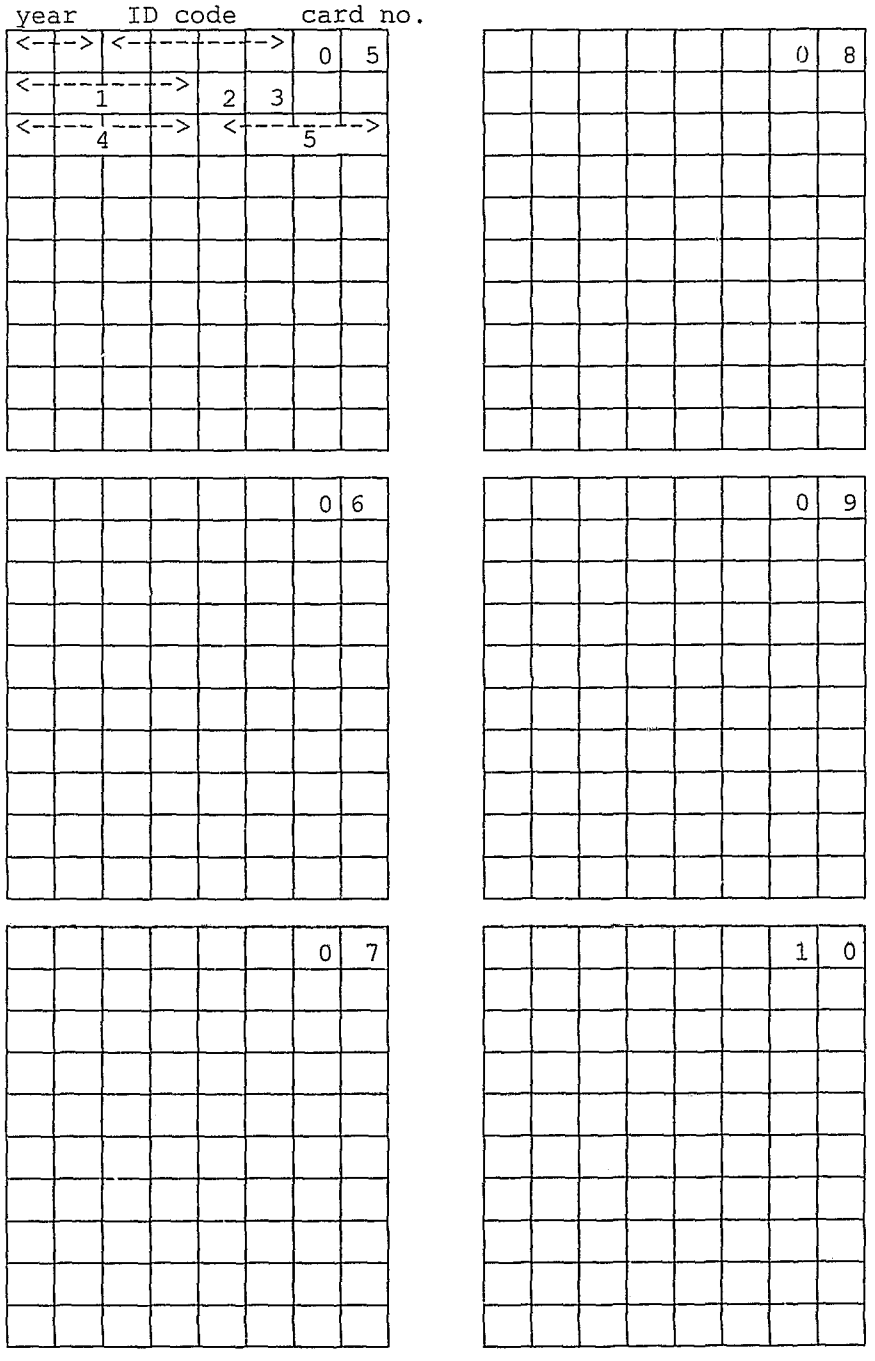
2. Do you receive fluoride rinses at school? yes no sometimes

3. Do receive fluoride treatments from your dentist or clinic?
yes no sometimes

4. Do you take fluoride tablets? yes no sometimes

EDUCATION	PRIMARY	HIGH	COLLEGE	TECHNICON	UNI-VERSITY	OTHER
FATHER						
MOTHER						

APPENDIX B. COMPUTER CODING SHEET - 1984 STUDY



Key to appendix B

1 = decimal age of subject

2 = sex (1=male, 2=female)

3 = ethnic group (8=rural black, 7=urban black, 3=urban Indian, 1=urban white)

4 = food code according to MRC Food Composition Tables and Codes (1986)

5 = food amount in grammes

APPENDIX C. FOOD FREQUENCY QUESTIONNAIRE - 1991 BIRTH-TO-TEN INTERCEPTION

Childs name.....
Ref. No.....
Sex.... Ethnic group... ...Clinic.....
Date of birth.....

Please determine/calculate how often your child consumes each of the food items mentioned below and indicate by means of an (X) in the appropriate frequency column. When letters are indicated in brackets alongside the food item, please use the letter in the appropriate frequency column to indicate which item/s are consumed.
* when an item is consumed more than 2/day indicate the number in the column.

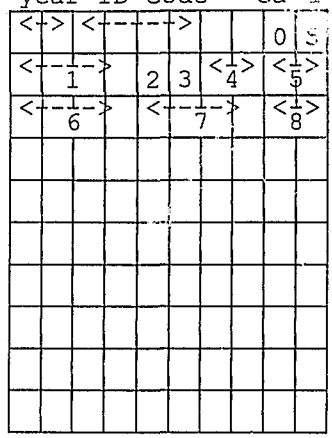
FOOD ITEM	SELDOM NEVER	1/ MTH	2-3 MTH	1/ WK	2-4/ WK	5-6/ WK	1/ DY	*2/ DY
milk (full cream(F)								
skimmed(S),low-fat(LF)								
squash/cordial								
carbonated beverage:								
sugar added								
sugar free								
Game (Isotonic)								
tea								
coffee								
milo(M),horlicks(H),								
cocoa(C), other-state								
CEREALS AND								
PORRIDGES								
sweetened cereal								
Rice Krispies								
Cornlakes(C)								
All Bran(A)								
Weetbix(W)								
Pronutro(P)								
Oats(O), Maltabella(M)								
mieliemeal-soft(MM)								
other - state								
BREAD, BISCUITS								
Bread white(W),brown(B)								
wholewheat(WW)								
crispbreads: Provita(P								
cream crackers(CR)								
other - state								

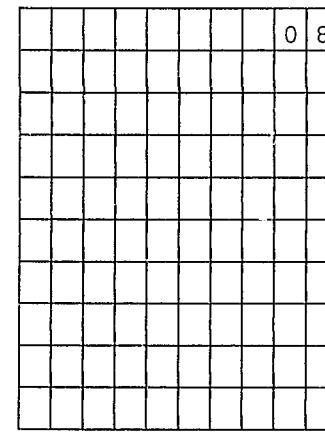
FOOD ITEM	SELDOM NEVER	1/ MTH	2-3 MTH	1/ WK	2-4/ WK	5-6/ WK	1/ DY	*2/ DY
SPREADS								
Margarine (M)),butter(B)								
peanut butter(PB)								
jam(J)								
marmite(MR)								
fish paste(FP)								
bovril(BR)								
other - state								
CAKES, PUDDINGS, SNACKS								
Cake(C), pastries(P),								
scone(S), doughnut(D),								
biscuits -plain(P)								
-filled(F)								
tarts-jam(J), milk(M)								
ice-cream								
custard								
jelly								
baked pudding								
instant pudding								
cream								
crisps								
peanuts								
popcorn								
SUGAR, SWEETS, CHOCOLATE								
sugar								
sweets-sucking(S)								
jelly(J)								
toffees(T)								
chocolate-plain(P)								
-bar(B)								
PROTEIN SOURCES								
yoghurt-plain(P)								
flavoured(F)								
beef-steak								
-stew,curry								
-roast								
-mince								
-meatballs								
-cottage pie								
-spaghetti								
bolognaise								

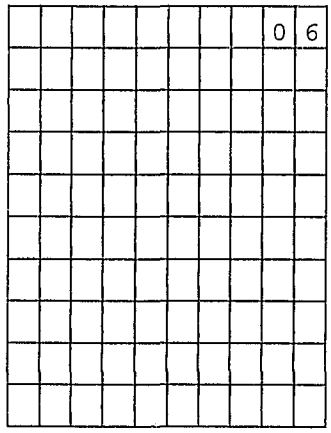
FOOD ITEM	SELDOM NEVER	1/ MTH	2-3/ MTH	1/ WK	2-4/ WK	5-6/ WK	1/ DY	*2 DY
-sausage								
-pie								
mutton-chops								
-stew,curry								
-roast								
pork-chops								
-stew,casserole								
-roast								
-sausage								
-sausage roll								
-boerewors								
-vienna								
-polony								
-ham								
-bacon								
chicken-stew								
-roast								
-pie								
gravy								
eggs								
cheese-cheddar(CH)								
Gouda(G)								
cottage(C)								
pizza								
macaroni cheese								
fish-Hake-fried(F)								
-baked(B)								
-pie(P)								
Tuna salad								
pilchards(P),								
sardines(S)								
STARCHES								
rice(R), pasta(P)								
mieliemeal-stiff								
samp/mielierice								
mielies								
FRUIT								
average fresh fruit								
juice								
average fresh fruit								
apple(A), banana(B),								
orange(O)								

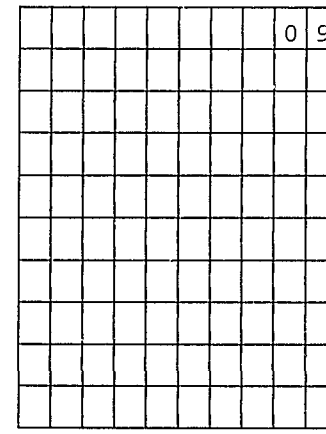
FOOD ITEM	SELDOM NEVER	1/ MTH	2-3 MTH	1/ WK	2-4/ WK	5-6/ WK	1/ DY	*2/ DY
tinned fruit								
dried fruit-prunes								
mixed(M), raisins(R)								
VEGETABLES								
potatoes-boiled								
-baked								
-mashed								
-roast								
-chips								
average green veg								
average yellow/red veg								
average white veg								
dried veg-beans								
-lentils								
baked beans								
salad greens(S)								
tomatoes-raw(R),								
cooked(C)								
SAUCES								
white sauce								
cheese sauce								
mayonnaise								
salad dressing								
mustard								
chutney								
tomato sauce								
OIL								
SOUP								
homemade(H),tinned(T)								

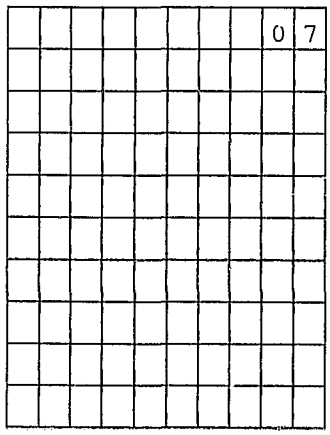
APPENDIX D. COMPUTER CODING SHEET -1991 AND 1995 BIRTH-TO-TEN INTERCEPTIONS

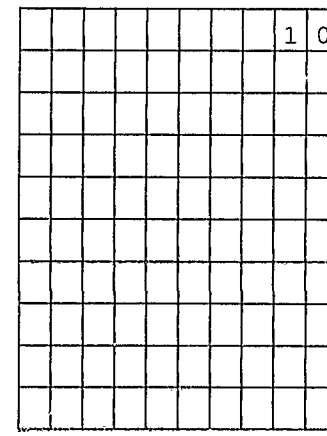












Key to appendix D

1 = decimal age of subject

2 = sex (1=male, 2=female)

3 = ethnic group (7=urban black, 5=urban "coloured", 3=urban Indian and 1=urban white)

4 = dietary assessment method (01=dietary record, 02=24-hour recall, 03=dietary history, and 04=food frequency questionnaire)

5 = day of recording (used mainly for dietary record ie. first(01), second(02) or third day(03), otherwise "00" if only one recording was done)

6 = food code according to the MRC Food Composition Tables and Codes (1991)

7 = food amount in grammes

8 = frequency of consumption

APPENDIX E. DENTAL RESEARCH INSTITUTE
MEDICAL RESEARCH COUNCIL/UNIVERSITY OF THE WITWATERSRAND
BIRTH TO TEN DENTAL SURVEY 1991

Name of child..... card1 1–7
Date of examination..... DRI case no
Clinic..... Age in years 8–9
(F=female M=male) Sex 10
(B=black C=coloured Indian=I Race 11
W=white)

Area 12–13
Occupation father..... Environment 14
mother.... Occupation 15–18
Education father..... Education 19–22
mother 23

Birth to Ten ID No 25–31
Streptococcus counts 32–37

Greene & Vermillion oral debris score tooth 55 51 65 75 71 85 38–43

Dental caries card2 1–7
Repeat DRI case no

	B	M	D	L	O			B	M	D	L	O	
Tooth 55	8					12	Tooth 65	30					34
Tooth 54	13					17	Tooth 64	35					39
Tooth 53	18					21	Tooth 63	40					43
Tooth 52	22					25	Tooth 62	44					47
Tooth 51	26					29	Tooth 61	48					51

Dental caries card3 1–7
Repeat DRI case no

	B	M	D	L	O			B	M	D	L	O	
Tooth 75	8					12	Tooth 85	30					34
Tooth 74	13					17	Tooth 84	35					39
Tooth 73	18					21	Tooth 83	40					43
Tooth 72	22					25	Tooth 82	44					47
Tooth 71	26					29	Tooth 81	48					51

card4 1–7
Repeat DRI case no

Tooth 8 55 54 53 52 51 61 62 63 64 65 85 84 83 82 81
71 72 73 74 75 27

Trauma Tooth 28 52 51 61 62 82 81 71 72 35

APPENDIX F. DENTAL RESEARCH INSTITUTE FOOD FREQUENCY QUESTIONNAIRE - 1995 BIRTH-TO-TEN INTERCEPTION

(based on Rowett Research Institute, Aberdeen, Scotland, for S.African populations)

FOR OFFICE USE ONLY

NAME_____ REFERENCE NUMBER _____
CLINIC WHEN CHILD WAS 1-YEAR-OLD(1991)_____
DATE OF BIRTH _____AGE (YEAR AND MONTHS)_____
SEX _____ ETHNIC GROUP _____ DIETARY ASSESSMENT METHOD _____
DAY OF RECORDING _____
SURVEY VENUE _____ SURVEY DATE _____

INSTRUCTIONS

Please complete **both** Section A and B of the questionnaire

SECTION A

The following questions in **Section A** are about the foods your child **USUALLY** eats during an average week. Please indicate the number of **days per week** that he/she eats each item on average. Ring the answer as in the examples:

If you eat the food every day, ring 7 7 6 5 4 3 2 1 M R
If you eat the food 3 days /week, ring 3 7 6 5 4 3 2 1 M R
If you eat the food only monthly, ring M 7 6 5 4 3 2 1 M R
If you never or rarely eat the food, ring R 7 6 5 4 3 2 1 M R
Where spaces are provided after a question please write your answer in the space.

GRAIN AND CEREAL GROUP

	No. days/week
Bread	7 6 5 4 3 2 1 M R
provitas/cream crackers etc.	7 6 5 4 3 2 1 M R

Does he/she mainly eat white, brown or wholewheat bread? _____

How many slices of bread does he/she have per day? _____

BREAKFAST CEREALS AND PORRIDGES

	No. days /week
cereals (Rice Krispies, Cornflakes)	7 6 5 4 3 2 1 M R
sugar coated cereals (Coco pops, Frosties)	7 6 5 4 3 2 1 M R
w/wheat cereals (All Bran, Weetbix)	7 6 5 4 3 2 1 M R
porridge (Oats, Maltabella, Maize meal)	7 6 5 4 3 2 1 M R
muesli	7 6 5 4 3 2 1 M R
pronutro	7 6 5 4 3 2 1 M R

OTHER STARCHES

	No. days/week
rice, pasta	7 6 5 4 3 2 1 M R
stiff maize meal - with amasi(sour milk)	7 6 5 4 3 2 1 M R
- without	7 6 5 4 3 2 1 M R
samp/mielie rice - with beans	7 6 5 4 3 2 1 M R
- without	7 6 5 4 3 2 1 M R

MEATS AND MEAT SUBSTITUTES

	No. days/week
red meat (beef, lamb, pork or mince)	7 6 5 4 3 2 1 M R
processed meat (bacon, sausages, polony)	7 6 5 4 3 2 1 M R
chicken	7 6 5 4 3 2 1 M R
fish	7 6 5 4 3 2 1 M R
eggs and egg dishes	7 6 5 4 3 2 1 M R
cheese, cheese spread and cheese dishes	7 6 5 4 3 2 1 M R
nuts, including peanut butter	7 6 5 4 3 2 1 M R
dried peas, beans, baked beans or legumes	7 6 5 4 3 2 1 M R

VEGETABLES AND FRUIT

	No. days /week
Green and/or yellow vegetables	7 6 5 4 3 2 1 M R
potatoes	7 6 5 4 3 2 1 M R
fresh fruit	7 6 5 4 3 2 1 M R
canned fruit	7 6 5 4 3 2 1 M R
dried fruit (raisins, prunes, dates)	7 6 5 4 3 2 1 M R
fresh fruit juice (Ceres, Liquifruit)	7 6 5 4 3 2 1 M R

Name some of the vegetables he/she has eaten this past week

_____

Does he/she eat his/her vegetables most frequently cooked or raw?

_____

Does he/she mainly eat his/her potatoes as boiled, baked in jacket, mashed, roasted or as chips?

_____

What types of fresh fruit has he/she eaten this past week?

_____

FATS AND OILS

	No. days/week
oil/butter/margarine	7 6 5 4 3 2 1 M R
salad dressing/mayonnaise	7 6 5 4 3 2 1 M R
cream	7 6 5 4 3 2 1 M R
non dairy creamers (Cremora)	7 6 5 4 3 2 1 M R
ice-cream	7 6 5 4 3 2 1 M R

Please estimate, on average, the total amount of butter or margarine your child has on his/her bread per day.
_____tsp.
How much oil/margarine/fat do you use in cooking his/her food per day _____ tsp.

	No. of days/week
How often do you fry his/her food	7 6 5 4 3 2 1 M R

MILK AND MILK PRODUCTS

	No. days/week
milk	7 6 5 4 3 2 1 M R
yoghurt - plain	7 6 5 4 3 2 1 M R
- flavoured	7 6 5 4 3 2 1 M R
milo/Nesquick/cocoa/Horlicks	7 6 5 4 3 2 1 M R
custard	7 6 5 4 3 2 1 M R

Please estimate, on average, how much milk your child has per day, including that on cereal, in tea or coffee and milk drinks
_____ml or _____cups

What type/s of milk does he/she usually have:
full-cream _____
low-fat (2% fat) _____
skimmed _____
condensed _____

MISCELLANEOUS

Please estimate how many teaspoons of sugar your child has, in total, per day? _____tsp. (in tea/coffee/milk drinks, on cereal/porrridge, added to vegetables)

	No. days/week
sweets (sucking/jelly type/fudge/toffee)	7 6 5 4 3 2 1 M R
chocolates/chocolate bars	7 6 5 4 3 2 1 M R
jam, syrup, honey	7 6 5 4 3 2 1 M R
jelly	7 6 5 4 3 2 1 M R
sweet biscuits,cakes, pastries, doughnuts, tarts, scones, crumpets	7 6 5 4 3 2 1 M R

	No. days/week
crisps	7 6 5 4 3 2 1 M R
popcorn (plain or candied)	7 6 5 4 3 2 1 M R
puddings (trifle, baked puddings etc.)	7 6 5 4 3 2 1 M R
coldrinks (Coke, Fanta etc) or cordials	
- sweetened	7 6 5 4 3 2 1 M R
- diet	7 6 5 4 3 2 1 M R
tea	7 6 5 4 3 2 1 M R
coffee	7 6 5 4 3 2 1 M R
spreads (bovril, marmite, fish paste, sandwich)	7 6 5 4 3 2 1 M R

How many meals does he/she eat per day ie. breakfast, lunch and/or dinner? _____

How many inbetween meal snacks does he/she eat per day ie. mid-morning, mid-afternoon and or late evening? _____(eg. If your child has a sweet half an hour after a meal consider it 1 inbetween meal snack. If he/she has a fruit juice an hour after a meal and then an hour later has a sandwich consider that 2 inbetween meal snacks).

SECTION B

Please indicate in **Section B** how many **portions** of the following food groups your child **ate yesterday** by circling the appropriate number.
Eg. If he/she had **1 egg** for breakfast, **cheese** for lunch and **chicken** for dinner, ring 3 for number 2.
If he/she had **cereal** and **1 slice of toast** for breakfast, a sandwich for lunch (**2 slices of bread**) and **rice** for dinner, ring 5 for number 6.

	No. Portions yesterday
1. milk, yoghurt (1portion = 1cup/200ml)	1 2 3 4 5 6 7 8 9 10
2. meat/fish/chicken/cheese/eggs/nuts/legumes	1 2 3 4 5 6 7 8 9 10
3. Fruit/fruit juice	1 2 3 4 5 6 7 8 9 10
4. vegetables (green and yellow)	1 2 3 4 5 6 7 8 9 10
5. potatoes	1 2 3 4 5 6 7 8 9 10
6. bread/cereal/porridge/rice/pasta/ maize meal/samp/mielie rice	1 2 3 4 5 6 7 8 9 10
7. oil/butter/margarine/cream/non dairy creamers/ salad dressings (1portion =1tspn)	1 2 3 4 5 6 7 8 9 10

Were these number of portions typical of what he/she would normally consume on an average day?

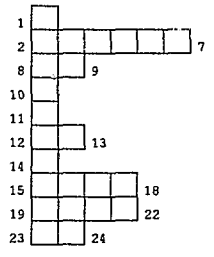
Yes _____ No _____

If you answered No, was the difference due to:
illness _____
a party _____
eating out _____
other reasons

_____

APPENDIX G. DENTAL RESEARCH INSTITUTE
MEDICAL RESEARCH COUNCIL/UNIVERSITY OF THE WITWATERSRAND
1995 BIRTH TO TEN SURVEY - DENTAL CARIES

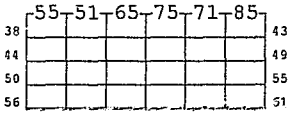
Name of child..... card1
Date of examination..... DRI case no
Clinic.....Age in years
(F M) Sex
(B, C, I, W) Race
Area
Occupation father..... Environment
mother..... Occupation
Education father..... Education
mother..... Fam income



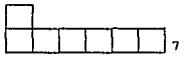
Birth to Ten ID No
Child Strep counts

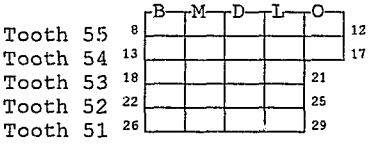


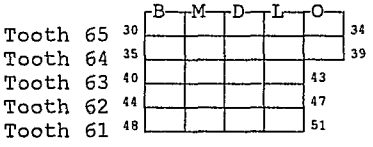
Greene & Vermillion oral debris score
Mother Strep counts



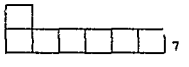
Dental caries
Repeat DRI card2
case no

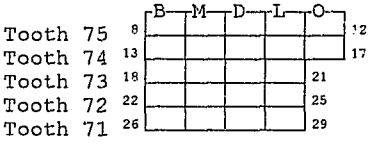


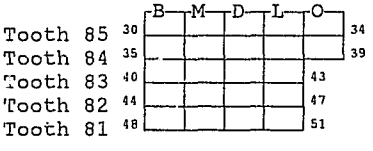




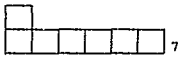
Dental caries
Repeat DRI case no card3





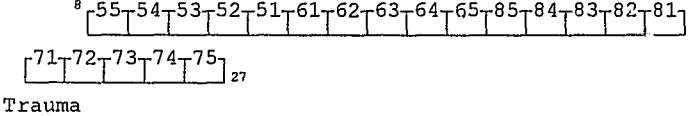


card4

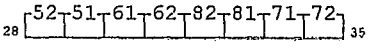


Repeat DRI case no

Hypoplasia



Trauma



APPENDIX H.

MANTEL-HAENSZEL X^2 TEST FOR TREND FOR CARIES GROUPS FOR THIRDS FOR ENERGY, MACRO- AND MICRONUTRIENTS

When the nutrients were divided into thirds (Table H.1), fat, cholesterol and added sugar were significantly related to caries prevalence for the whole group with caries scores classified into 3 (classification 2) and 4 (classification 3) dmfs groups, but no macronutrients showed any significance for the longitudinal group (Table H.2).

Among the micronutrients (Table H.3) calcium, riboflavin and vitamin E were significantly or, almost significantly, related to caries incidence for the whole group. Calcium was highly significant with $P<0.008$ for 4 (classification 3) dmfs score groups. Vitamin B12 was almost significant ($P<0.058$) for 4 (classification 3) dmfs groups of caries scores only, showing no significance for 2 (classification 1) or 3 (classification 2) score groups. For the longitudinal group (Table H.4) only calcium, riboflavin and vitamin E were almost significant.

Table H.1 Mantel-Haenszel x^2 test for trend for caries groups (thirds) I. Macronutrients for whole group n=423 (df =1 for all nutrients)

Nutrient	classification 1		classification 2		classification 3	
	x^2	P	x^2	P	x^2	P
energy	1.27	0.260	1.26	0.262	2.28	0.131
protein	0.04	0.846	0.38	0.536	0.60	0.437
fat	2.95	0.086	4.30	0.038*	4.93	0.026*
cholesterol	1.65	0.200	3.87	0.049*	4.20	0.040*
total available carbohydrate	1.06	0.304	2.17	0.141	2.65	0.104
fibre	1.48	0.224	2.41	0.121	3.27	0.071
added sugar	2.08	0.150	5.15	0.023*	6.25	0.012*

* = statistically significant ($P<0.05$)

classification 1 = dmfs scores <0 or >0

classification 2 = dmfs scores 0, 1-4, ≥5

classification 3 = dmfs scores 0, 1-4, 5-9, ≥10

Table H.2 Mantel-Haenszel x^2 test for trend for caries groups (thirds) I. Macronutrients for longitudinal group n=300 (df=1 for all nutrients)

Nutrient	classification 1		classification 2		classification 3	
	x^2	P	x^2	P	x^2	P
energy	0.70	0.403	1.35	0.246	1.68	0.196
protein	0.02	0.885	0.45	0.501	0.47	0.491
fat	0.98	0.321	1.70	0.192	1.87	0.172
cholesterol	0.04	0.849	0.97	0.325	1.15	0.283
total available carbohydrate	1.14	0.287	2.14	0.144	2.33	0.127
fibre	0.00	0.968	0.04	0.846	0.12	0.730
added sugar	0.32	0.572	1.27	0.260	1.25	0.263

* = statistically significant ($P<0.05$)

classification 1 = dmfs scores <0 or >0

classification 2 = dmfs scores 0, 1-4, ≥5

classification 3 = dmfs scores 0, 1-4, 5-9, ≥10

Table H.3 Mantel-Haenszel x^2 test for trend for caries groups (thirds) II. Micronutrients for whole group n=423 (df =1 for all nutrients)

Nutrient	classification 1		classification 2		classification 3	
	x^2	P	x^2	P	x^2	P
calcium	2.64	0.104	6.39	0.011*	7.08	0.008*
vitamin B12	0.52	0.469	3.25	0.071	3.58	0.058*
iron	0.81	0.369	1.98	0.159	2.80	0.094
magnesium	0.00	1.000	0.08	0.778	0.32	0.594
phosphorus	0.31	0.579	0.66	0.417	0.69	0.407
potassium	2.39	0.122	2.57	0.109	2.48	0.116
sodium	0.17	0.676	0.02	0.884	0.01	0.913
zinc	0.23	0.634	0.92	0.337	0.97	0.325
copper	1.45	0.228	2.46	0.117	2.21	0.137
vitamin A (RE)	0.30	0.584	1.64	0.200	2.06	0.151
thiamin	1.16	0.282	2.37	0.124	2.16	0.142
riboflavin	1.27	0.259	5.60	0.018*	6.13	0.013*
nicotinic acid	0.23	0.629	0.18	0.675	0.15	0.697
vitamin B6	0.62	0.432	0.30	0.584	0.19	0.664
folic acid	0.09	0.763	0.22	0.642	0.45	0.500
ascorbic acid	0.59	0.441	1.37	0.243	2.03	0.154
pantothenic acid	1.59	0.207	2.69	0.101	2.88	0.090
biotin	0.01	0.930	0.48	0.486	0.34	0.561
vitamin D	0.32	0.572	2.06	0.151	3.02	0.082
vitamin E	1.57	0.210	3.74	0.053*	5.89	0.015*
manganese	3.29	0.070	2.96	0.085	3.53	0.060

* = statistically significant ($P<0.05$)

classification 1 = dmfs scores <0 or >0

classification 2 = dmfs scores 0, 1-4, ≥5

classification 3 = dmfs scores 0, 1-4, 5-9, ≥10

Table H.4 Mantel-Haenszel x^2 test for trend for caries groups (thirds) II. Micronutrients for longitudinal group n=300 (df=1 for all nutrients)

Nutrient	classification 1		classification 2		classification 3	
	x^2	P	x^2	P	x^2	P
calcium	1.15	0.285	3.61	0.057*	3.57	0.059*
vitamin B12	0.06	0.815	1.05	0.306	0.95	0.330
iron	0.73	0.394	2.30	0.130	3.07	0.080
magnesium	0.09	0.761	0.05	0.829	0.00	0.981
phosphorus	0.35	0.552	0.82	0 365	0.61	0.434
potassium	1.41	0.236	1.69	0.194	1.65	0.200
sodium	0.23	0.635	0.06	0.806	0.13	0.721
zinc	0.43	0.512	1.44	0.230	1.04	0.307
copper	0.44	0.509	1.14	0.285	0.93	0.334
vitamin A (RE)	0.02	0.889	0.16	0.688	0.22	0.638
thiamin	0.40	0.530	1.24	0.266	0.81	0.368
riboflavin	0.31	0.578	3.29	0.070	3.59	0.058*
nicotinic acid	0.05	0.817	0.03	0.863	0.04	0.840
vitamin B6	0.14	0.708	0.14	0.705	0.15	0.703
folic acid	0.16	0.691	0.24	0.624	0.31	0.580
ascorbic acid	0.19	0.665	0.82	0.365	1.52	0.218
pantothenic acid	0.26	0.609	0.99	0.319	0.91	0.340
biotin	0.68	0.410	0.00	0.955	0.07	0.790
vitamin D	0.29	0.589	0.24	0.628	0.52	0.470
vitamin E	0.73	0.393	2.49	0.115	3.79	0.052*
manganese	0.54	0.463	0.34	0.560	0.52	0.470

* = statistically significant ($P<0.05$)

classification 1 = dmfs scores <0 or >0

classification 2 = dmfs scores 0, 1-4, ≥5

classification 3 = dmfs scores 0, 1-4, 5-9, ≥10

APPENDIX I.

FREQUENCY DISTRIBUTION OF CARIES SCORES BY THIRDS FOR ASSOCIATED NUTRIENTS

Table I.1 Frequency distribution of four dmfs score groups by thirds of fat
whole group n=423

	Thirds			
dmfs score	1	2	3	total
	<78	≥78<103	≥103	
0 n (%)	58 (36)	63 (39)	42 (26)	163 (101)
1-4 n (%)	41 (34)	42 (35)	38 (31)	121 (100)
5-9 n (%)	23 (28)	31 (38)	27 (33)	81 (99)
≥10 n (%)	15 (26)	19 (33)	24 (41)	58 (100)
total	137	155	131	

Table I.2 Frequency distribution of four dmfs score groups by thirds of cholesterol
whole group n=423

	Thirds			
dmfs score	1	2	3	total
	<245	≥245<351	≥351	
0 n (%)	61 (37)	53 (33)	49 (30)	163 (100)
1-4 n (%)	41 (34)	47 (39)	33 (27)	121 (100)
5-9 n (%)	27 (33)	19 (23)	35 (43)	81 (99)
≥10 n (%)	13 (22)	24 (41)	21 (36)	58 (99)
total	142	143	138	

Table I.3 Frequency distribution of four dmfs score groups by thirds of added sugar
whole group n=423

	Thirds			
dmfs score	1	2	3	total
	<59	≥59<86	≥86	
0 n (%)	54 (33)	66 (40)	43 (26)	163 (99)
1-4 n (%)	42 (35)	45 (37)	34 (28)	121 (100)
5-9 n (%)	20 (25)	33 (41)	28 (35)	81 (101)
≥10 n (%)	15 (26)	16 (28)	27 (47)	58 (101)
total	131	160	132	

Table I.4 Frequency distribution of four dmfs score groups by thirds of calcium
whole group n=423

	Thirds			
dmfs score	1	2	3	total
	<509	≥509<738	≥738	
0 n (%)	63 (39)	54 (33)	46 (28)	163 (100)
1-4 n (%)	46 (38)	41 (34)	34 (28)	121 (100)
5-9 n (%)	18 (22)	36 (44)	27 (33)	81 (99)
≥10 n (%)	16 (28)	16 (28)	26 (45)	58 (101)
total	143	147	133	

Table I.5 Frequency distribution of four dmfs score groups by thirds of vitamin B12
whole group n=423

	Thirds			
dmfs score	1	2	3	total
	<2.1	≥2.1<2.9	≥2.9	
0 n (%)	60 (37)	52 (32)	51 (31)	163 (100)
1-4 n (%)	50 (41)	37 (31)	34 (28)	121 (100)
5-9 n (%)	21 (26)	29 (36)	31 (38)	81 (100)
≥10 n (%)	14 (24)	23 (40)	21 (36)	58 (100)
total	145	141	137	

Table I.6 Frequency distribution of four dmfs score groups by thirds of riboflavin

whole group n=423

	Thirds			
dmfs score	1	2	3	total
	<0.9	≥0.9<1.3	≥1.3	
0 n (%)	57 (35)	53 (33)	53 (33)	163 (101)
1-4 n (%)	43 (36)	46 (38)	32 (26)	121 (100)
5-9 n (%)	15 (19)	35 (43)	31 (38)	81 (100)
≥10 n (%)	13 (22)	20 (34)	25 (43)	58 (99)
total	128	154	141	

Table I.7 Frequency distribution of four dmfs score groups by thirds of vitamin E

whole group n=423

	Thirds			
dmfs score	1	2	3	total
	<11.3	≥11.3<18.9	≥18.9	
0 n (%)	55 (34)	62 (38)	46 (28)	163 (100)
1-4 n (%)	43 (36)	41 (34)	37 (31)	121 (101)
5-9 n (%)	25 (31)	29 (36)	27 (33)	81 (100)
≥10 n (%)	14 (24)	14 (24)	30 (52)	58 (100)
total	137	146	140	

Table I.8 Frequency distribution of four dmfs score groups by thirds of calcium

longitudinal group n=300

	Thirds			
dmfs score	1	2	3	total
	<509	≥509<738	≥738	
0 n (%)	44 (38)	41 (35)	31 (27)	116 (100)
1-4 n (%)	36 (40)	29 (33)	24 (27)	89 (100)
5-9 n (%)	13 (21)	28 (46)	20 (33)	61 (100)
≥10 n (%)	10 (29)	11 (32)	13 (38)	34 (99)
total	103	109	88	

Table I.9 Frequency distribution of four dmfs score groups by thirds of riboflavin longitudinal group n=300

	Thirds			
dmfs score	1	2	3	total
	<0.9	≥0.9<1.3	≥1.3	
0 n (%)	41 (35)	40 (34)	35 (30)	116 (99)
1-4 n (%)	34 (38)	36 (40)	19 (21)	89 (99)
5-9 n (%)	13 (21)	25 (41)	23 (38)	61 (100)
≥10 n (%)	7 (21)	15 (44)	12 (35)	34 (100)
total	95	116	89	

Table I.10 Frequency distribution of four dmfs score groups by thirds of vitamin E longitudinal group n=300

	Thirds			
dmfs score	1	2	3	total
	<11.3	≥11.3<18.9	≥18.9	
0 n (%)	41 (35)	44 (38)	31 (27)	116 (100)
1-4 n (%)	34 (38)	31 (35)	24 (27)	89 (100)
5-9 n (%)	18 (30)	24 (39)	19 (31)	61 (100)
≥10 n (%)	8 (24)	10 (29)	16 (47)	34 (100)
total	101	109	90	

Table I.11 Frequency distribution of three dmfs score groups by thirds of fat whole group n=423

	Thirds			
dmfs score	1	2	3	total
	<78	≥78<103	≥103	
0 n (%)	58 (36)	63 (39)	42 (26)	163 (101)
1-4 n (%)	41 (34)	42 (35)	38 (31)	121 (100)
≥5 n (%)	38 (27)	50 (36)	51 (37)	139 (100)
total	137	155	131	

Table I.12 Frequency distribution of three dmfs score groups by thirds of cholesterol whole group n=423

	Thirds			
dmfs score	1	2	3	total
	<245	≥245<351	≥351	
0 n (%)	61 (37)	53 (33)	49 (30)	163 (100)
1-4 n (%)	41 (34)	47 (39)	33 (27)	121 (100)
≥5 n (%)	40 (29)	43 (31)	56 (40)	139 (100)
total	142	143	138	

Table I.13 Frequency distribution of three dmfs score groups by thirds of added sugar whole group n=423

	Thirds			
dmfs score	1	2	3	total
	<59	≥59<86	≥86	
0 n (%)	54 (33)	66 (40)	43 (26)	163 (99)
1-4 n (%)	42 (35)	45 (37)	34 (28)	121 (100)
≥5 n (%)	35 (25)	49 (35)	55 (40)	139 (100)
total	131	60	132	

Table I.14 Frequency distribution of three dmfs score groups by thirds of riboflavin whole group n=423

	Thirds			
dmfs score	1	2	3	total
	<0.9	≥0.9<1.3	≥1.3	
0 n (%)	57 (35)	53 (33)	53 (33)	163 (101)
1-4 n (%)	43 (36)	46 (38)	32 (26)	121 (100)
≥5 n (%)	28 (20)	55 (40)	56 (40)	139 (100)
total	128	154	141	

Table I.15 Frequency distribution of three dmfs score groups by thirds of vitamin E
whole group n=423

	Thirds			
dmfs score	1	2	3	total
	<11.3	≥11.3<18.9	≥18.9	
0 n (%)	55 (34)	62 (38)	46 (28)	163 (100)
1-4 n (%)	43 (36)	41 (34)	37 (31)	121 (101)
≥5 n (%)	39 (28)	43 (31)	57 (41)	139 (100)
total	137	146	140	

Table I.16 Frequency distribution of three dmfs score groups by thirds of calcium
whole group n=423

	Thirds			
dmfs score	1	2	3	total
	<509	≥509<738	≥738	
0 n (%)	63 (39)	54 (33)	46 (28)	163 (100)
1-4 n (%)	46 (38)	41 (34)	34 (28)	121 (100)
≥5 n (%)	34 (24)	52 (37)	53 (38)	139 (99)
total	143	147	133	

Table I.17 Frequency distribution of three dmfs score groups by thirds of calcium longitudinal group n=300

	Thirds			
dmfs score	1	2	3	total
	<509	≥509<738	≥738	
0 n (%)	44 (38)	41 (35)	31 (27)	163 (100)
1-4 n (%)	36 (40)	29 (33)	24 (27)	89 (100)
≥5 n (%)	23 (24)	39 (41)	33 (35)	95 (100)
total	103	109	88	

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