On Carbohydrate Intake and Dental Status in the Elderly

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Abstract

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People's dental status has the potential to affect dietary intake and, at the same time, diet may affect the health of the dentition. To study the associations, the elderly appear to be an appropriate group and carbohydrates the appropriate nutrients. The aim of the thesis was to explore the associations between intake of carbohydrates and dental status in the elderly.

A number of different elderly cohorts in Göteborg (the H70 Studies) have been examined both cross sectionally and longitudinally regarding their intake of carbohydrates. Dieticians conducted the interviews based on the diet history method. The intake of energy and carbohydrates was analysed using food tables from the National Swedish Food Administration. There were differences between cohorts but no clear longitudinal trend. Most differences between cohorts followed the trend of supply data relating to the consumption in Sweden.

To examine the inter-relationships between different carbohydrates, energy intake and the intake of other macronutrients, a factor analysis was performed. Using six factors, as much as 90% of the variation could be explained. Of these factors, four were related to the intake of carbohydrates. To analyse patterns within the samples, a k-mean cluster analysis was performed. A model with seven clusters explained no less than 40% of the original variation. The different clusters were associated with background factors such as gender, education, BMI and dental status.

Dentists or dental hygienists examined the cohorts regarding their dental status. To analyse the relationship between dental status and the intake of nutrients, a graphic interaction model, including cohort, gender, education, height, smoking habits, BMI, modified Eichner index (as the measure of dental status), subjective health and dietary intake, was built. All the nutrient variables were included in a factor analysis and eight factors were found which once again explained about 90% of the variation: four of them were related to the intake of carbohydrates. The dental status was related to the intake of monosaccharides, sucrose and lactose and furthermore to cholesterol. A higher intake of sucrose was associated with a poorer dental status, and with a higher prevalence of dental caries.

In order to study the associations between oral function and dental caries, a number of different measurements were assessed in a sub-sample of elderly people (n = 92). The variables within different areas were reduced by factor analysis and they were then included in stepwise regression models. Chewing efficiency and motoric ability was for example related to oral sugar clearance, and chewing time with the prevalence of dental caries.

In conclusion, these findings show that the carbohydrate intake among the elderly is mostly influenced by cohort and period and less by age. However, dental status appears to be a factor that independently plays a significant part and, as a result, it should be included in nutritional epidemiological studies.

Key words: Carbohydrates, Cohort analysis, Dental caries, Dental status, Elderly, Epidemiology, Factor analysis, Graphic interaction model, Oral sugar clearance

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Der Hauptmangel alles bisherigen Materialismus – den Feuerbachschen mit eingerechnet – ist, daß der Gegenstand, die Wirklichkeit, Sinnlichkeit, nur unter der Form des Objekts oder der Anschauung gefaßt wird; nicht aber als menschliche sinnliche Tätigkeit, Praxis, nicht subjektiv. Daher geschah es, daß die tätige Seite, im Gegensatz zum Materialismus, vom Idealismus entwickelt wurde – aber nur abstrakt, da der Idealismus natürlich die wirkliche, sinnliche Tätigkeit als solche nicht kennt. Feuerbach will sinnliche, von den Gedankenobjekten wirklich unterschiedene Objekte; aber er faßt die menschliche Tätigkeit selbst nicht als gegenständliche Tätigkeit. ... Er begreift daher nicht die Bedeutung der „revolutionären“, der „praktisch-kritischen“ Tätigkeit.

The chief defect of all hitherto existing materialism - that of Feuerbach included - is that the thing, reality, sensuousness, is conceived only in the form of the object or of contemplation, but not as sensuous human activity, practice, not subjectively. Hence, in contradistinction to materialism, the active side was developed abstractly by idealism -- which, of course, does not know real, sensuous activity as such. Feuerbach wants sensuous objects, really distinct from the thought objects, but he does not conceive human activity itself as objective activity. ... Hence he does not grasp the significance of "revolutionary", of "practical-critical", activity.

Huvudfelet med all hittillsvarande materialism (Feuerbachs inräknad) är att föremålet, verkligheten, sinnevärlden, bara uppfattas som objekt eller som åskådning; däremot inte som sinnlig mänsklig verksamhet, inte som praxis; inte subjektivt. Detta är anledningen till att den verksamma sidan utvecklats av idealismen men inte av materialismen - men bara abstrakt, eftersom idealismen naturligtvis inte känner den verkliga, sinnliga verksamheten. Feuerbach syftar till sinnliga - från tankeobjekten verkligt åtskilda objekt: men han fattar inte själva den mänskliga verksamheten som en verksamhet riktad mot objektet. ... Han förstår därför inte betydelsen av den "revolutionära", den "praktiskt-kritiska" verksamheten.

Karl Marx. Thesen über Feuerbach (1845)

Contents

Original papers

I. Alstad T, Österberg T, Rothenberg E, Steen B, Birkhed D (1999). Intake of monosaccharides, sucrose and fibre in the elderly – a cross-sectional and longitudinal study. *Scand J Nutr* **43**:147-52.

II. Alstad T, Österberg T, Steen B, Birkhed D (2001). Intake of lactose, starch and different fibres in the elderly – a cross-sectional and longitudinal study. *Scand J Nutr* **45**:25-7.

III. Alstad T, Holmberg I, Österberg T, Steen B, Birkhed D (2006). Patterns of carbohydrate intake – a study of typology, associations and changes over time in an elderly Swedish population. *J Nutr Health Aging* **10**:401-7.

IV. Alstad T. Better dental status among the elderly is associated with an improved diet – a study of four 70-year-old cohorts between 1971 and 2001- in manuscript.

V. Alstad T, Österberg T, Holmberg I, Birkhed D (2008). Associations between oral sugar clearance, dental caries and related factors among 71-year-olds. *Acta Odont Scand* accepted 30 July 2008.

Introduction

A large number of studies among elderly people have found that more teeth increase the intake of primarily fruit and vegetables and thereby ascorbic acid and dietary fibres for example (Sheiham et al. 2001, Marcenes et al. 2003, Sahyoun & Krall 2003, Lee et al. 2004, Suzuki et al. 2006, Nowjack-Raymer & Sheiham 2007). There are also data showing a better nutritional status among those individuals with more teeth in the form of higher blood levels of ascorbic acid and beta-carotene (Bailey et al. 2004, Semba et al. 2006, Musacchio et al. 2007, Nowjack-Raymer & Sheiham 2007). Some studies have also found that, the more teeth, the lower the average BMI (Sahyoun et al. 2003) but the opposite is also described (Kim et al. 2007). However, these results could be explained by other factors, as primarily social factors. Both a higher diet quality and more teeth are associated with a higher social status (Cabrera et al. 2007, Österberg et al. 2006). A further problem is that a poor diet may cause dental diseases.

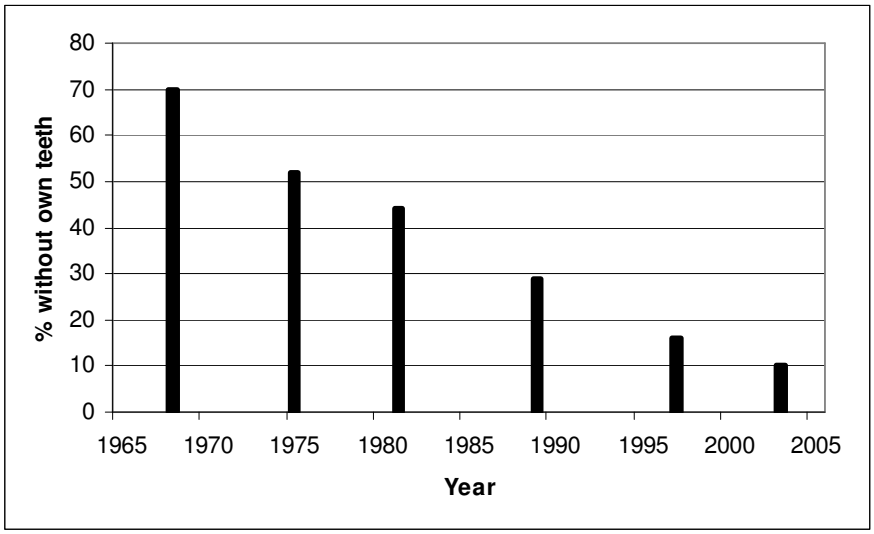


Figure 1. The percentage of people in Sweden at the age 65 to 74 that claim in telephone interviews that they do not have teeth of their own (Nordström 2006).

Moynihan (2005) has written a recent review of the association between diet and dental diseases. The associations between periodontitis and diet are mostly weak and the only strong association is between severe vitamin C deficiency and so called scurvy-related periodontitis. Dental caries on the other hand is related to diet. Countries with a supply of white sugar

(sucrose) below 50 g/day have a consistently low caries experience. However, the relationship between sucrose intake and caries prevalence is diminishing in western countries (Sreebny 1982, Woodward & Walker 1994, König & Navia 1995). There is a debate about the impact of monosaccharides and starch, as they have the potential to induce dental caries, but, at the same time, they are seldom related to dental caries in epidemiological studies (König & Navia 1995, Moynihan 2005, Lingström et al. 2000 and 2005). Dental caries still appears to be the major cause of tooth losses among the elderly in Sweden and Germany (Fure 2003, Mack 2004) and a diet high in sucrose may therefore explain the relationship between diet and number of teeth.

Elderly in Sweden have a large variation in dental status (Österberg et al. 2006) and dietary intake (Eiben et al. 2004) and both vary over time (Swedish Board of Agriculture 2007, Sreebny 1982, Woodward & Walker 1994, Nordström 2006). The overall aim of this thesis is therefore to analyse the interaction between diet and dental status among the elderly.

Background

The H70 Studies

The gerontological and geriatric population studies in Göteborg, Sweden (H-70), are prospective cohort studies and have been in progress since the beginning of the 1970s. The aims of these prospective studies were "to make a survey of the social and medical conditions of the population, to obtain basic data for planning the care of the elderly, to contribute to the knowledge of normal ageing processes and of normal criteria within the age group and to offer the subjects a thorough medical examination. Furthermore, inclusion of several cohorts of the same chronological age should allow cohort comparisons" (Steen & Djurfeldt, 1993). A number of different cohorts have been followed, mostly from the age of 70. The general procedure, sampling and response rate have been described previously for the different cohorts and those participating in dietary and dental examinations (Rinder et al. 1975, Eriksson et al. 1987, Steen & Djurfeldt 1993, Eiben et al. 2004, Österberg et al. 2006). The studies include medical, dental, psychological and nutritional examinations and socio-economic data. The dietary and dental examinations are generally performed in sub-samples (Eiben et al. 2004, Österberg et al. 2006).

An H70 Study enables analyses of interactions between diet and dental status among elderly people and offers an opportunity to adjust for context and dynamic changes. The studies used in this thesis are all based on examinations within the H70 Studies.

Epidemiology of intake of carbohydrates among the elderly

Depending on the degree of polymerisation, carbohydrates can be divided into sugars (1-2 monomers), oligosaccharides (3-9 monomers) and polysaccharides (10 or more monomers) (Cummings & Stephen 2007, Mann et al. 2007). In the "Food tables of the National Swedish Food Administration" (1988), carbohydrates are divided into total monosaccharides, glucose, fructose, total disaccharides, sucrose, lactose, maltose, starch, total dietary fibres, cellulose, total non-cellulose polysaccharides (NCP), pectin, water-soluble NCP, water non-soluble NCP, total NCP, lignin (polysaccharides) and total carbohydrates. In the computerised tables (PC-Kost 2000), only total monosaccharides, total disaccharides, sucrose, (sugars), total dietary fibres (polysaccharides) and total carbohydrates are included.

Becker et al. (1994) compared different epidemiological dietary studies in Sweden published between 1950 and 1990 and conducted among the elderly. The intake of carbohydrate ranged from 45 to 51 E%. The lowest intakes are from the Dalby study (Dahlquist & Asp 1979), where the elderly men had an intake of 45 E% and the women 46 E%. Nordström et al. (1988), who studied elderly people in Umeå, presented results relating to six different groups with an intake range of between 47 and 51 E%, where the highest was found among 70-year-old women and the lowest among 79-year-old men. The only studies based on the total population of elderly people in Sweden (Becker, 1994, Becker & Pearson 2002) also found an intake of between 47 and 49 E% among those over 65 years of age. So, despite the time span and different methods, all these studies produced similar results.

With the exception of the Dalby study (Asp et al. 1979), most studies published before 1990 do not present results relating to different carbohydrates. In the Dalby study, the intake of fibre was analysed with a special method (the so called papain-amylase digestion procedure) and the investigators found an intake of 21 g/day among women and 27 g/day among men. In later studies, Becker (1994) found an intake of total dietary fibre among the elderly of 16 g/day (women) and 19 g/day (men), while in "Riksmaten 1997-98" (Becker & Pearson 2002) the corresponding results were 20 g/day in both sexes.

The intake of sugars among the elderly in the "Hulk study" (Becker, 1994) was 7-8 E% sucrose and 6-7 E% monosaccharides. "Riksmaten 1997-98" (Becker & Pearson 2002) reported an intake of 8-9 E% sucrose, 7-8 E% monosaccharides and 4 E% of other disaccharides. In the Dalby study, the intake of glucose was 2-3 E%, sucrose 8 E% and lactose 3 E%. The only study including the intake of starch was the Dalby study, with an intake of 20 E% among women and 18 E% among men.

According to the Nordic Nutritional Recommendations (Nordic Council of Ministers 2004), the minimum requirement of carbohydrates is about 10-20 E%, if ketosis is to be avoided. There is also a maximum level of about 85 E%, but a range between 40 and 70 E% can be used as practical limits. Within these limits, a healthy diet in terms of carbohydrates is possible. The current recommendation is to increase the intake of carbohydrates to 55-60 E%. This increase in carbohydrates should be based on foods rich in complex carbohydrates, such as vegetables, fruit and cereals. There is also a maximum recommendation of 10 E% regarding the intake of refined sugars. There are two reasons for this recommendation: 1/ a larger amount makes it difficult to get enough of the required micronutrients, and 2/ the risk of caries increases with an increased intake of sugars. The recommended intake of dietary fibres is 25-35 g/day or 3 g/MJ. This recommendation can be difficult to achieve without a

higher carbohydrate intake and a lower intake of sucrose compared with the normal Nordic diet. The three recommendations relating to the amount of carbohydrates, refined sugars and dietary fibres are thereby inter-related (Nordic Council of Ministers 2004). These recommendations may have an increased role to play among the elderly, as the energy need declines with age and the need for a nutritious diet therefore increases (James 1989).

Compared with the recommendations, the mean intake found in the epidemiological studies among elderly in Sweden of total carbohydrates and dietary fibres is too low, but the intake of sucrose is in accordance with the recommendations. However, to the author's knowledge, no epidemiological study among the elderly has analysed the changes over time in the intake of different carbohydrates or analysed the associations between the intakes of different carbohydrates.

Carbohydrates and dental status

One of the most decisive studies regarding the relationship between dental caries and the intake of carbohydrates is the Vipeholm Study from 1947-51 (Gustafsson 1952). The Vipeholm Study was conducted to answer the question of whether or not the carbohydrates (sugars) influenced dental caries and if so how? The authors concluded that (Gustafsson 1952):

1. An increased consumption of sucrose may induce an increase in dental caries
2. The risk of developing dental caries increases if the sugar-containing food has a tendency to be retained in the oral cavity
3. The risk is further enhanced if the sugar-containing food is taken in frequently as a snack
4. Among those who ate three times a day, the caries activity was low, even if the meals were supplemented with substantial amounts of sucrose
5. The differences between individuals were pronounced
6. Even if sucrose was totally removed from the diet, dental caries still occurred

Based on the first four findings, the concept of "sugar time" was developed. "Sugar time" depends on two factors, 1/ the frequency of intake of fermentable carbohydrate and 2/ the elimination of the carbohydrates from the oral cavity. To measure the sugar elimination, a test of oral sugar clearance was used in the Vipeholm Study and it has subsequently been further developed by Hase et al. (1987). Oral sugar clearance is dependent on saliva production, chewing ability and the type of food (Hase 1993). The oral clearance could be of special

importance in the elderly, as it appears to be reduced by age (Hase et al. 1987, Lundgren et al. 1997). Whether it is reduced by ageing per se or by the increasing frequency of disease and medication is the subject of discussion, as these later factors may cause hyposalivation, for example (Fure & Zickert 1990, Österberg et al. 1982).

One important conclusion from the Vipeholm Study was that all dental caries could not be explained by the "sugar time". Krasse (2001) discusses the findings that some did not get caries despite high frequency intake of sucrose and some got caries despite very low intake. He concludes that among some people sugar and other carbohydrates play a minor role as causal factors. However, starches may have played the same role as sugars regarding "sugar time" if they were retained for a long time after meals (Lingström et al. 2000). As the functional oral ability of the participants of Vipeholm Study differed substantially this could explain why some people got caries despite both a low intake of sucrose and a low frequency. Both Hase et al. (1987) and Lundgren et al. (1997) found associations between measurements of oral function and sugar elimination among the elderly. However, neither of them conducted any analyses of interaction between these factors and dental caries. Therefore a study of the interaction between oral function and oral clearance and their impact on dental caries seems important to carry out.

Dental status and dietary intake

Many epidemiological studies of the elderly have found an association between dental status and the intake of different foods or nutrient status (Österberg and Steen 1982, Geissler & Bates 1984, Sahyoun & Krall 2003, Marcenes et al. 2003, Lee et al. 2004, Bailey et al. 2004, Suzuki et al. 2006, Semba et al. 2006, Musacchio et al. 2007, Nowjack-Raymer & Sheiham 2007). Individuals with few or no teeth often have a lower intake of fruit, vegetables and meat together with a higher intake of easily chewed foods, like porridge, cakes and buns.

Westergren et al. (2002) found three components of eating difficulties among institutionalised elderly people, namely 1/ ingestion, 2/ deglutition (chewing and swallowing) and 3/ energy intake. They compared patients after a stroke with patients with orthopaedic problems. Problems with ingestion and deglutition were commonly found in patients referred after a stroke, whereas patients with orthopaedic problems more frequently had problems with energy intake. Andersson et al. (2002) made oral assessments of institutionalised elderly and found that swallowing problems had the strongest association with nutritional status and oral problems were also common in these groups. Posner et al. (1994) made an analysis of

associations between demographic and health characteristics of New England elders. They found a positive association between a good dental status and a good nutrient intake. They also found a negative association between dental decay and good nutrient intake. Lamy et al. (1999) concluded that among institutionalised elderly poor oral status increased eating difficulties, increased the intake of mashed food and decreased eating pleasure. The subjects with these problems also had a higher risk of undernutrition.

Tsuga et al. (1998) investigated the association between dental status and self-assessed masticatory in a sample of 80-year-old subjects. They found that the ability was associated with dental status and also bite force. Locker et al. (2002) followed a sample of elderly over seven years and found a substantial increase in chewing problems, especially among those with poor dental and general health. Weight loss has also been found to be associated with dental status (Ritchie et al. 2000). The results imply a causal association between poor dental status and poor nutritional status among frail and sick elderly.

Fontijn-Tekamp et al. (1996) used data from different locations in Europe and USA to analyse the impact of dentition on diet in the elderly and concluded that substantial differences existed. They could not find a common impact in the different locations. However, when Nowjack-Raymer & Sheiham (2007) compiled data from all parts of the USA, they found associations between more teeth and a higher intake of dietary fibres and higher levels of beta-carotene and ascorbic acid in the blood. They were able to adjust for more social factors than Fontijn-Tekamp et al. (1996) and this perhaps explains the difference.

One way of studying the association between dental status and dietary intake is to improve the dental status. Elmståhl *et al.* (1988) presented results from patients admitted to geriatric long-stay wards. After having their dentures improved, many of them started to eat foods like crispbread. Sandström and Lindquist (1987) found that their patients ate more crispbread and fruit after having been treated with tissue-integrated prostheses, but, although the intake of some foods increased, none of the studies reported a significant change in any nutrient. Allen & McMillan (2001) found significant improvements in chewing among subjects receiving implant prostheses but no change in diet. However, the material was limited and the statistical power was therefore low.

Nevertheless, the results further underline the importance of capturing the complexity of the inter-relationships between dental status and dietary intake. Further, they point to the need to be able simultaneously to analyse the impact of foods on dental status and dental status on foods.

Aims

The overall aim of this thesis was to analyse aspects of the way the dental status interacts with dietary intake among elderly people in Göteborg. To achieve this, the aims of the studies were to:

1. Analyse the variation in the intake of carbohydrates among elderly people by:
    a. Describing cross-sectional and longitudinal changes
    b. Analysing associations between carbohydrates
2. Analyse the interaction between the dietary intake and dental status
3. Analyse in more detail the associations between oral function, oral sugar clearance and dental caries

Populations and discussion of the populations

The H70 Studies comprise a number of cohorts followed in most cases from the age of 70 and onward. To date, six different cohorts have been studied and five of them have contributed to the results in this thesis (Figure 2). All the cohorts were randomly selected to be representative of the population in Göteborg (Rinder et al. 1975, Eriksson et al. 1987, Steen & Djurfeldt 1993, Eiben et al. 2004). The first 70-year-old cohort was born in 1901-02 (C1-70), the third in 1911-12 (C3-70), the fifth in 1922-23 (C5-70) and the sixth in 1930-31 (C6-70). The two 79- to 80-year-old subjects were born in 1901-02 (C1-79 (a re-examination of C1-70)) and in 1915 (cohort 4) (C4-80 (a re-examination of the Göteborg-participants from the NORA (Nordic Research on Aging) study (Schroll et al. 1993)). The samples were obtained from the Revenue Office Register and the response rates were 85% (C1), 77% (C3), 66% (C5) and 65% (C6), respectively, among the 70-year-old subjects.

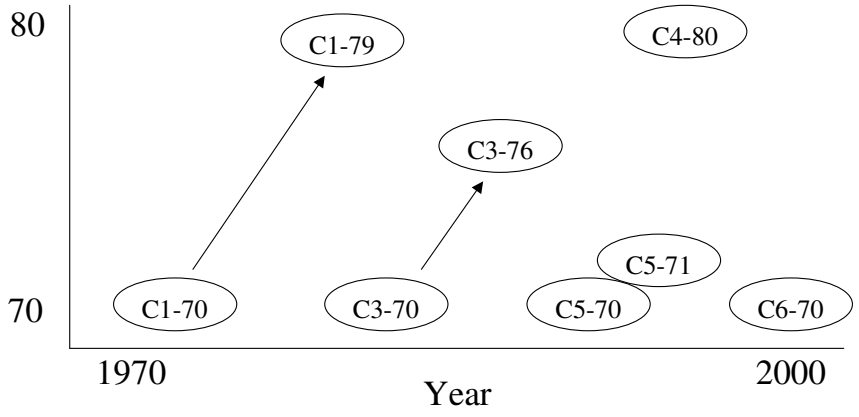


Figure 2. The samples used in the studies. Arrows indicate longitudinal interviews.

To investigate longitudinal changes in carbohydrate intake, all the subjects in cohort 1, who were examined both as 70-year-olds and as 79-year-olds, were analysed (C1-79) (Figure 2). Furthermore, a sample from cohort C3 was re-examined as 76-year-olds (C3-76) and they were also included in the longitudinal analysis.

The samples also differed between papers as the different analyses differed; for example, in Paper II, only 97 of the 76-year-olds in cohort 3 were included as they were included in a

longitudinal analysis, whereas 151 were included in Paper III as they were used in cross-sectional analyses. Only probands living at home were included in the studies. In Paper V, a consecutive sample of 120 subjects from the fifth cohort was selected based on their number of teeth.

Table 1. Baseline samples C1 and C3-C6. Missing data relate to both dietary data and dental data. The figures within parentheses refer to the percentage of the original samples.

Baseline studies							
	(cohort-age)	C1-70	C3 -70	C4 -75[1]	C5 -70	C5 –71	C6 -70
Total fully examined		973 (85%)	619 (77%)	301 (68%)	500 (66%)	93 (78%)	550 (65%)
Dietary interview sub-samples		390	303		250		550
Living in institution		10	5		5		
Refusal or non co-operation		20	36		51		
Outliers or missing data							
	Paper III	9	16				
	Paper IV	16	22		67		117
	Paper V					1	
Participants	Paper I	360	262		194		
	Paper II	360	262				
	Paper III	351	246				
	Paper IV	344	240		127		433
	Paper V					92	
Follow-up studies							
	Cohort Age	C1-79	C3 -76	C4 -80			
			/878				
Death during follow-up		113	41/	58			
Refusal or non co-operation		62	41/229	64			
Living in institution		7	0/37	6			
Missing data			83/552				
Total sample		178	97/60	173			
Participants	Paper I	178	97/	173			
	Paper II	178	97/				
Outliers or missing data		9	6				
Participants	Paper III	169	151				

In Table 1 the baseline samples and dropouts are presented. The rate of participation went from 85% in the first to 65% in the sixth cohort. The higher the response rate, the better, but there is no magic figure specifying how high it must be (Mundy 2002). In some instances it was possible to describe the dropouts (e.g. Rinder et al. 1975, Eriksson et al. 1987, Bergh et al. 2003) and there were both random and systematic errors. Increasing non-participating rates must be considered a potential source of bias and therefore the results concerning both dietary intake and dental status must be validated both internally and externally.

Methods and discussion of the methods

Dietary examinations

The dietary interviews were performed in subgroups with the dietary history method (Burke (1947) modified for the elderly by Steen et al. (1977). Rothenberg et al. (1996) and Eiben et al. (2004) have described the dietary interviews. Some features of the dietary interviews have changed over time. At the beginning of the 1990s the interviews started to use open registration. One example is fresh vegetables that were interpreted as tomatoes before the 1990s but were subsequently analysed as the actual vegetable. The way in which quantities (amounts) were described also changed over time (Rothenberg et al. 1996). However, this was generally a reflection of the dietary changes that took place rather than a methodological change.

The food tables used in Papers I-IV were all based on tables from the National Swedish Food Administration's food tables (1988, 1992, 2000). There were some substantial changes over time, the most pronounced of which related to the energy from dietary fibres. When the fibres are fermented together with other non-digested carbohydrates, some of the end products are short-chain fatty acids. These can be absorbed and utilised as energy by the epithelial cells (butyrate) and by the rest of the body (pyruvate and acetate). The importance of this energy yield is the subject of discussion, but McNeil (1988) estimates that it can supply as much as 10% of our energy needs. In the study by Livesey et al. (1995), five dietary supplements were studied in terms of digestible energy. They found that the amount varied from 0.3 to 10.4 kJ/g and that this was related to the fermentability of the fibres. These discussions and results have resulted in different views of the energy in foods containing dietary fibres, from 17 kJ/g originally to 0 kJ/g during the 1990s to now, where it has changed to 8 kJ/g in the most recent food tables (Nordic Council of Ministers 2004).

The ability of a food to elevate the concentration and duration of glucose in the blood is measured by the glycaemic index and presented in tables (Foster-Powell et al. 2002). The glycaemic index or load appears to have been studied on a large scale in recent years within epidemiology in terms of carbohydrates and health effects (e.g. Jenkins et al. 2002, Ebbeling et al. 2007, Lajous et al. 2008). However, the usefulness of the tables has been questioned (Flint et al. 2004) and also the physiological effects (Kiens& Richter 1996). FAO/WHO limit their recommendation to using it only when choosing between two similar carbohydrate-

containing foods, while still considering intra- and inter-individual variations (Mann *et al.* 2007). None of the studies in this thesis considers the glycaemic index or loads of the diet.

One difficulty when it comes to comparing the different studies in this thesis has been the use of different editions of the food tables. Another problem is that the foods in the diet history interview were not directly applicable to the food tables, so they had to be interpreted. Two different interpretations and thereby two different food tables have been used in the studies, one in Papers I and IV and another in Papers II and III. Comparing the intake in different genders, cohorts and ages using the two food tables revealed that in most cases there were only minor differences (1-3%), but there are also differences exceeding 10%. There were no systematic differences between cohorts, ages, genders or different carbohydrates.

All individual dietary measurements are in a way based on narrative methods, making response bias a major problem. As a result, what we measure is not only what people eat but also what they remember having eaten or what they eat when focused upon it, what they would like to have eaten or eat, and what they think that we wanted them to have eaten, for example (Johansson et al. 1998). This response bias is a major problem as the studies can never be blinded or double-blinded. Energy intake, sucrose intake and their relationship to BMI appear to be a problematic area of this kind. The OPEN study (Subar et al. 2003, Kipnis et al. 2003) found problems associated with the under-reporting of energy and protein intake when comparing interview methods with biomarkers (Double Labelled Water (Prentice et al. 1985) and urinary nitrogen (Isaksson 1980)). The under-reporting increased with increasing BMI and it seemed clear that energy intake was the main problem. Two of the conclusions from the OPEN study were that the precision in dietary studies is low, creating an attenuation of the results, and that the validity of the energy intake is such that it has to be discussed in studies. Livingstone et al. (1990) using double labelled water technique found that the lower the recorded energy intake was, the larger the error, but this could be due to a too low mean energy intake in the sample together with a lower precision.

When comparing the results between intake from interviews and supply data sucrose appears to be the carbohydrate that differs. The intake from our studies and the nationwide studies (Becker 1994 and Becker & Pearson 2002) indicates an intake of around 50 g/day, whereas the supply data indicate an intake above 100 g/day (Swedish Board of Agriculture 2007), which means that nearly 1 MJ/person-day is not accounted for in the interviews.

Walter Willett has written a paper on the trustworthiness of conclusions based on nutritional epidemiology (Willett 2007). His conclusion is that the trustworthiness is lower than claimed in national health recommendations and he exemplifies this by discussing the

recommendation to lower the fat intake. His point is that we should discuss the different fats and different carbohydrates rather than the proportions of total intake. In spite of this, the study he uses to make his point (McCullough M et al. 2002) is not without its limitations, including questionable sampling, problems concerning indexing, measurement and statistical techniques. Although his criticism seems fair, his conclusions and solutions are questionable. He ends up with many of the problems discussed by Bingham (1987), Dean et al. (1993) and Spicer (2005), such as response bias, sampling bias and problem associated with model choice. The best way forward appears to be the advice given by Dean et al. (1993) to use multi-methods and focus more attention on the theoretical part of science.

Dental examinations

The teeth were examined using a mirror, probe and radiographs in Cohort 1, with mirror, probe in Cohort 3, and with radiographs in Cohort 5 and 6. Only manifest, presumably active carious lesions extending well into the dentine were recorded. Some of the following variables were used: DT, FT, MT, number of teeth, Eichner Index (see glossary) and modified Eichner Index (also including artificial teeth in bridges as occluding teeth (Österberg & Landt, 1976)). Specially trained dentists and dental hygienists, different in different cohorts, performed these examinations.

The author (TA) performed the dental examination in Paper V, as well as the tests of oral function: 1) oral muscular co-ordination ability (Landt & Fransson 1975), 2) masticatory efficiency (Tzakis et al. 1989) and 3) mandibular movements (Karlsson et al. 1991). The techniques are described in Paper V. Specially trained laboratory technicians conducted salivary tests. These procedures are described in detail in Paper V.

Models and statistics

Dean et al. (1993) discuss the question of appropriate concepts regarding both theory and method related to public health and they discuss, for example, the problem of causation, the role of theory and the relationship between theory and methods. They recommend more account-centred work (more focus on interaction between variables) instead of variable centred (e.g. risk-factor analyses that focus on one variable and one effect) (Dean et al. 1993). They also recommend using models based on conditional independence, such as graphic

interaction models (Whittaker 1993) and latent structure models (e.g. Kim J-O & Mueller C (1978a+b)).

A model as the one in used in Paper IV may be built in the following way.

1. **Define the theoretical domain**. In Paper IV it was the interactions between dental status and diet.
2. **Include previous knowledge**. Based on other studies, measures of age, cohort, gender, social status, smoking habits, BMI, health and, of course, dental status and diet were needed.
3. **Choose and measure manifest variables**.
4. **Create the database**. Which variables are to be used in the analyses? In Paper IV the dietary variables were reduced by factor analysis and among the dental variables modified Eichner Index was chosen based on higher correlations with macronutrients.
5. **Consider possible interactions and build the model**. In Paper IV the model is based on life-course considerations, meaning that things that happen early in life can influence what happens later in life but cannot be influenced back by these later events.
6. **Test the model**. Parametric partial correlation was used in Paper IV, as this allowed testing both between a dependent and an independent variable and also between two dependent variables. The tests proceed from the first variable area into the next with tests between two variables while the others are adjusted for. If the association is statistically significant then the association is conditionally independent, depending on the variables you have adjusted for.
7. **Interpret your final model**. Does it show anything meaningful or do the results only seem to be scattered findings? Do the individual variables behave as expected or do they deviate?

A graphic presentation of a model makes it easy to compare it with other studies. For example, Nowjack-Raymer & Sheiham (2007) did not adjust for BMI as was done in Paper IV. However, as can be seen in the model, BMI definitely has the potential of altering the results, as the association between BMI and Eichner Index was conditionally independent and as BMI was also related to sucrose intake. Maybe that is one explanation of why they did not find an association between sucrose intake and number of teeth?

Time changes are of special theoretical interest in dietary studies and they can be divided into cohort, period and age effects (Dean et al. 1993, Firebaugh 1997). The problem is that there is no foolproof way to separate them and it is therefore important to make careful assumptions about their nature in order to separate the effects (Firebaugh 1997). By

comparing the results from special studies including longitudinal data (as in ours), nationwide (like Becker (1994) and Becker & Pearson (2002)) and supply data (like Swedish Board of Agriculture (2007)), it is possible to obtain a hint about what is happening. The increase in fruit and vegetable intake that occurred during the period between 1970 and 2000 was clearly visible in the supply data (Swedish Board of Agriculture 2007). It was also visible in the cohort comparisons but not in the longitudinal ones. If we compare this with the findings from nationwide studies, they show that women eat more fruit and vegetables than men. However, there are no significant differences between ages (Becker & Pearson 2002), but an increase over time between the two nationwide studies (Becker 1994 and Becker & Pearson 2002). It therefore seems as though the increasing consumption of vegetables is a period effect and not a cohort or age effect.

When studying associations, there is a need for methods that use previous knowledge and the appropriate statistical methods and produce results that make it possible to acquire new knowledge. When it comes to complex situations such as the association between dental status and carbohydrate intake, where associations can go in different directions, methods such as multiple regression analysis are not appropriate (Tacq 1997, Dean et al. 1993). The method proposed in the book by Dean et al. (1993), i.e. graphical interaction models and latent variable methods, appears to be more appropriate. The concept of starting by constructing a theoretical model based on previous knowledge, using statistical methods that do not per se assume specific relationships or directions and, finally, on the basis of the results revising the theoretical model, appears justifiable. This way of analysing is very much in line with Bayesian statistics (Iversen 1984), but these methods were not used in the present studies, even if they could be of interest in the future.

Both parametric and non-parametric statistical tests were used as the nonparametric permutation test, based on Pitman's test variable, that was used in Paper I and II, and the parametric ANOVA, MANOVA and regression analysis used in Paper III and V. Both the multinomial logistic regression in Paper III and the partial correlation analyses in Paper IV are also parametric tests. The partial correlation that was used could be replaced by non-parametric analysis of partial correlations, which would further minimise the assumptions, but, as all the samples were of the size of about a hundred or more and the assumption of parametric distribution is robust (Spicer 2005), the problem appears to be less serious. Another way to tackle the assumptions relating to distributions is to use bootstrapping methods (Mooney & Duval 1993) to evaluate the sensitivity of the results. This could have been an advantage especially in Paper V when the two different stepwise procedures came up

with different results. All three methods, Bayesian statistics, non-parametric tests and bootstrapping, could be of value to study and use within the framework of graphic interaction models.

Among the explorative analyses two different types of factor analysis were performed. Principal component analysis with Varimax rotation was used in Paper III and V, and a principal component analysis with Direct Oblimin rotation was used in Paper IV. Varimax has the advantage of creating orthogonal dimensions whereas the dimensions created by Oblimin are sometimes easier to interpret. If the dimensions are going to be used within a larger model, as in Paper IV, the dimensions will not be orthogonal as their associations are adjusted for by other variables. Therefore Direct Oblimin seems to be a good option within models.

P-values ≤ 0.05 are considered statistically significant throughout the thesis.

Results and discussion of the results

Analyses of the variation in carbohydrate intake

Some of the carbohydrates displayed a clear trend over time, such as the increase in monosaccharides and dietary fibre and, to a lesser degree, the decrease in sucrose intake. Total carbohydrates, starch and lactose also displayed statistically significant trends but with ups and downs between cohorts (Table 3). Total carbohydrates, lactose and starch all had a maximum in the third cohort (C3), but lactose displayed a downward trend in overall terms, while total carbohydrates and starch displayed an upward trend. The major difference is the approximately 30% increase in the intake of monosaccharides and dietary fibre between 1971 and 2001. The supply of total carbohydrates in g/person-day increased by 2% from 1970 to 2000 (from 344 to 354 g/person-day), which is close to the 5% found in this study. The increase in dietary fibre supply between 1980 and 2000 was 21% (19 to 22 g/person-day) compared with 10% in this study. The supply of sucrose was steady during the entire period, and was about 115 g/person-day. The difference between supply and interview data for sucrose explains most of the difference in the intake of total carbohydrates between supply and interview.

The National Swedish Food Administration (Livsmedelsverket 2007) has presented calculations of the supply of monosaccharides between 1980 and 2000. They found an increase from about 30 to more than 40 g/person-day, which is nearly exactly the same as the results in the present studies. There are no data regarding the supply of lactose, but, as milk is the major source, it is possible to make an appreciation. Calculations based on 5 gram lactose per 100g milk and 2 gram lactose per 100 gram fermented milk shows an increase from about 22 g/person-day in 1970 to 24 g/person-day in 1980 and a drop to 18 g/person-day in 2000. This is lower than the results presented here, but the trend is the same. To estimate the supply of starch you may subtract the intake of sugars and dietary fibre from the supply of total carbohydrates. The supply of starch would then be approximate 155 g/person/day, which is close to the findings in Papers II and III.

There are two difficulties comparing supply data with interview data: 1/ waste that is not accounted for and 2/ referring to different populations. A recent Swedish study reported losses of about 18% in foodservice institutions (Karlsson 2002). Children in schools left starchy foods on their plates while restaurant guest left vegetables. In private households the waste

seems to be smaller but amounts to about 5%. There are no data referring to the elderly people.

Table 2. Cohort difference in carbohydrate intake in grams in four 70-year-olds cohorts. The results presented here relate to people who also underwent a dental examination. Differences between cohorts are tested with ANOVA and test of trend with partial correlation, in both cases adjusted for gender. From Paper IV.

	Cohort				p-values	
g/day	C1-70 F/M[4]	C3-70 F/M	C5-70 F/M	C6-70 F/M	Diff between cohorts[3]	Test of trend[3]
Total carbohydrates	212/258	220/274	209/260	222/272	0.010	0.025
Monosaccharides	32/32	31/34	38/41	41/43	<0.001	<0.001
Sucrose	46/56	39/52	38/46	39/50	<0.001	0.001
Lactose[1]	24/27	27/32	23/28	23/26	<0.001	0.042
Starch[2]	109/143	123/158	110/145	119/152	<0.001	0.006
Dietary fibre	16/18	19/21	20/22	21/23	<0.001	<0.001

[1] Residual disaccharides
[2] Residual carbohydrates
[3] Adjusted for gender
[4] F= female, M = male

Two national studies of the intake of carbohydrates at different ages were performed in 1989 and 1997, but the elderly were only a separate group in the second of these (Becker 1994, Becker & Pearson 2002). In Riksmaten 1997-98 (Becker & Pearson 2002), the elderly did not deviate in any substantial way from the rest of the population in terms of their total carbohydrate intake. Their intake of sucrose, monosaccharides and dietary fibres was close to the results presented in Table 2. According to Riksmaten 1997-98 (Becker & Pearson 2002), the intake of both monosaccharides and dietary fibres is higher among the elderly than in the rest of the population. The intake of lactose and starch can be estimated and in both cases the results are similar to the results in Papers II and IV. The findings relating to monosaccharides, lactose, starch and dietary fibre are therefore trustworthy but there are validity problems regarding sucrose.

The difference in the intake of sucrose in grams in the different cohorts was not unexpected, as it appears to be the same in other studies. Johansson et al. (1998) found that

the energy intake from dietary interviews deviated from the expected intake, depending on BMI and lifestyle factors. The finding in Paper IV of a negative partial correlation between sucrose intake and BMI appears to suggest that there was some under-reporting, particularly among people with a higher BMI. This is in line with the findings of Johansson et al. (1998) and the OPEN study (Subar et al. 2003, Kipnis et al. 2003). These facts underline the importance of adjusting for both energy intake and BMI when studies of associations between sucrose and health are performed.

Hultén et al. (1990) found that the number of items included in the diet history interview could influence the total energy intake. The interviews in C5 and C6 were more open in the sense that the exact food was registered, whereas in C1 and C3 the foods were chosen in advance. This could influence both amount and diversity, but, as the trend is in line with the supply data for most nutrients this appears to be a minor problem and cannot explain the low intake of sucrose. Another reason could be problems with the samples. Supply data refer to the general Swedish population and the results presented here are from Göteborg. However, there are no results from other studies indicating that the sucrose intake is considerably lower in Göteborg than elsewhere (Becker 1994, Becker & Pearson 2002). The dropouts are also unlikely to explain the difference as they were modest in the first cohort. Lupton (1996 p 150) writes about the ambivalence around sugar and sweetened foods of both gratification and guilt relating to sugar and sweetened foods. Sugar and sweetened foods are "bad for your health but good for your pleasure" and their intake therefore becomes a moral question. This dilemma may even increase if the individual is overweight and this dilemma is probably a major determinant of the discrepancy seen between the supply and interview data.

Longitudinal trends were not as clear as the cohort trends. Only two cohorts, C1 and C3, were followed longitudinally and the results are presented in Papers I and II. The most striking result was that, taken as E%, almost no intake of carbohydrates changed longitudinally. The only mutual trend, apart from no trend, was a decreased intake of fruits and vegetables as the individuals grew older. The change over time may therefore be primarily due to cohort and period effects than to an age effect (Wolinsky 1993).

In the conclusion from the joint FAO/WHO Scientific Update on carbohydrates in Human Nutrition (Mann et al. 2007) the following can be read: "a single value for carbohydrate cannot reflect the range of carbohydrate components or their diverse nutritional properties" (Mann et al. 2007 p S133). The results of the present studies may add the conclusion that they also differ separately over time as well. However, as the FAO/WHO paper also concludes, there is no simple translation from carbohydrate intake to nutritional

effects. Different suggestions, such as the concept of added sugars, free sugars, glycaemic index or glycaemic load, do not seem appropriate in most cases (Mann et al. 2007).

Analyses of associations between nutrients

In Papers III and IV, the nutrients were analysed in terms of potential latent variables. The reasons behind this were twofold:

1. To reduce the number of nutrient variables if possible
2. To obtain conditional independent variables describing the nutrient intake

Factor analyses were used to create and study the potential latent variables. In both papers, principal component analysis was used to extract the dimensions, but two different methods for rotating the dimensions were used. In both cases, a strong reduction in variables was achieved without losing a substantial part of the original variation. In Paper III, 21 variables were reduced to six dimensions, while retaining 91% of the original variation, and, in Paper IV, 37 variables were reduced to eight dimensions while retaining 87% of the original. Even if the problem of representation appeared small, the problem of interpretation may be substantial. This was not a problem in any case in the analyses, as all dimensions had a clearly visible major component (Table 3).

Table 3. The different dimensions found in the two factor analyses in Papers III and IV. The nutrient variable with the highest correlation are presented.

Dimension	Paper III	Paper IV
1	Starch (g)	Starch (g)
2	Cellulose (g/MJ)	Monosaccharides (E%)
3	Sucrose (E%)	Lactose (E%)
4	Lactose (E%)	Sucrose (E%)
5	Monosaccharides (E%)	Cholesterol (E%)
6	WisNCP[1] (g/MJ)	Retinol eqv
7		PUFA[2] (E%)
8		SFA[3] (E%)

[1] Water insoluble Non Cellulose Polysaccharides
[2] Poly unsaturated fatty acids
[3] Saturated fatty acids

The dietary dimensions found in Paper III were used in a cluster analysis. The purpose was to explore the possibility that there were clusters of eating patterns among the individuals. The K-mean clustering technique was used and seven different clusters were found (Table 4). The explained variance (adjusted R^2) of the original 21 nutrient variables differed between 24% and 47%.

Table 4. The original nutrient variables and food groups associated with the different clusters. Results from three-way ANOVA adjusting for gender and cohort.

	Small eaters	Lean and green eaters	Fruit eaters	Sweet tooth eaters	Gourmands	Milk drinkers	Fat eaters
Nutrient	Starch (E%)	Dietary fibres (g+E%)	Monosaccharides (g+E%)	Sucrose (g+E%)	Energy (MJ) Starch (g) Fat (g)	Lactose (g+E%)	Total fat (E%)
Food group			Fruits	Other foods[3]	Potatoes Cereals Meat/Fat	Dairy products	

[1] Water-soluble non-cellulose polysaccharides
[2] Water-insoluble non-cellulose polysaccharides
[3] Foods that do not belong within the food circle, e.g. white sugar, fruit syrup, candy, fizzy drinks

Although the clusters appeared both interpretable and reasonable, a large part of the original variation in the nutrients was lost. In spite of this, it seems obvious that there was some meaningful structure in the population that could be useful for a typology, as found in other similar studies (Quatromoni et al. 2002). On the other hand, the analysis of latent variables (the factor analysis) lost less of the variation and was also easy to interpret. Factor analyses were therefore used in both Paper IV and Paper V.

There was an age effect regarding the clusters towards a higher proportion of the older elderly people (76 and 79-year-olds) being “small eaters”. This could be interpreted as a fall back on the starch dimensions and is perhaps in line with interpreting the starch dimension as a core dietary variable at least in an elderly Swedish population. When elderly people reduce their dietary intake the last thing they maintain is their intake of starchy products, such as bread and potatoes. Moreiras et al. (1996) also found a decline in intake of energy with age in other European countries and USA. This smaller and less varied intake has nutritional implications, as the elderly need a high quality diet but get the opposite.

Analyses of the interaction between dietary intake and dental status

Associations between the carbohydrate intake and background variables were analysed in Papers III and IV. In Paper III, the main focus was on whether the clusters were meaningful in relation to diet and diet-related factors. Variables such as education, BMI and Eichner Index were related to the different clusters, which indirectly made them interesting for the analyses in Paper IV. As the focus shifted to the associations between diet and dental status in Paper IV, the usefulness of clusters diminished but the importance of dimensions remained.

In Paper IV a Graphic Interaction Model (GIM) was used (Whittaker 1993). The variables of gender, cohort, height, education, smoking habits, BMI, modified Eichner Index, feeling healthy and intake of nutrients (eight dimensions based on factor analysis) were used.

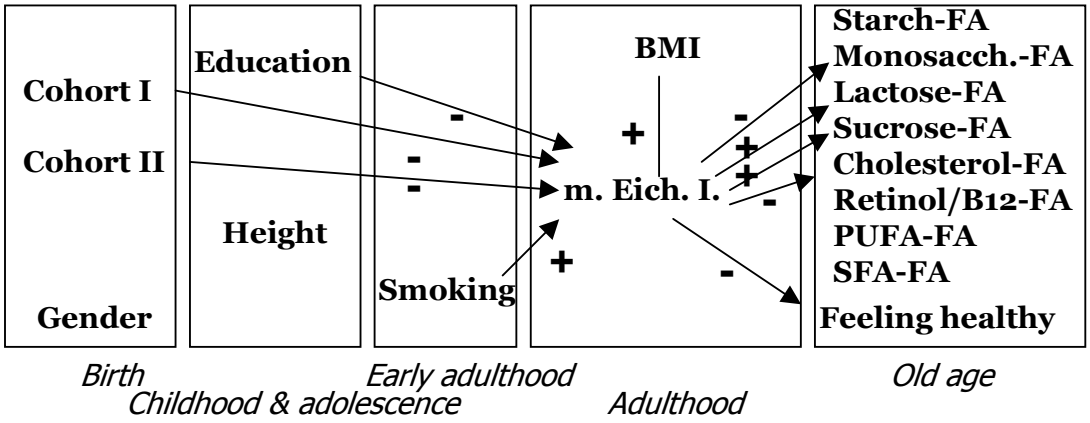


Figure 3. Graphic interaction model displaying the conditional independent associations of dental status measured as the modified Eichner Index. The arrows represent associations between an explanatory and a response variable while the lines represent associations with two-way interaction. Only statistically significant associations are included and only those associated with the modified Eichner Index.

The results regarding the modified Eichner Index are presented in Figure 3. The five different variable areas are presented as boxes, with the first to the left (Birth) and the last to the right (Old age). The modified Eichner Index was related to 14 of 23 variables. The arrows or lines in the figure indicate a conditionally independent association between the variables. The arrow between smoking and the modified Eichner index means that they were associated even when adjusted for gender, cohort I + II (early or late changes), education, height and BMI. In other words, the association is adjusted for the other variables in the previous or the same box, but not, to the later boxes. This is a conditionally independent association. The plus sign

means that smoking was positively associated with the modified Eichner Index, meaning that smokers had worse dental status than former or non-smokers.

Kim et al. (2007) found that BMI was positively associated with the number of teeth whereas in the present study the association is negative. However, in the study by Kim et al. the population had very low values of BMI (below 25 in all groups), whereas the mean BMI in the present studies is above 25. Maybe this is a U-shaped association, i.e. those with a BMI of about 25 have the highest number of teeth, whereas the number of teeth decreases for those with a BMI both below and above 25?

The main findings were the associations between dental status and dietary intake. The modified Eichner Index was associated with the latent variables related to the intake of all three sugars and with cholesterol. Those individuals with a poorer dental status have a higher intake of foods high in sucrose and lactose but a lower intake of foods high in monosaccharides and cholesterol. This has been primarily interpreted as an effect of chewing ability, as both sucrose and lactose are associated with foods that are easy to chew, such as cakes, buns and dairy products. Monosaccharides and cholesterol, on the other hand, are associated with products requiring a greater chewing ability, such as fruit and meat. This interpretation is further confirmed by the fact that the modified Eichner Index was more closely related to the intake than the number of teeth. The main difference between the Eichner Index and number of teeth was that the number of teeth does not measure the ability to use them when chewing, but the modified Eichner Index does.

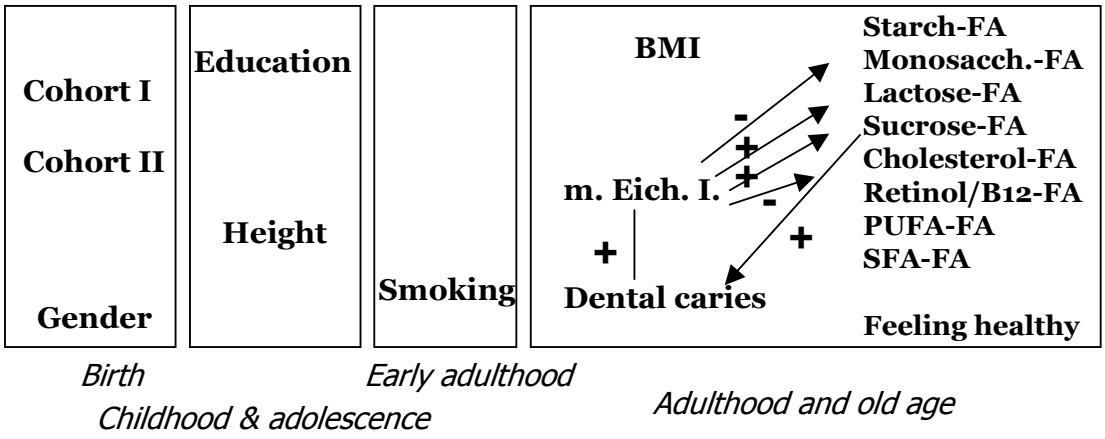
There were also other findings worth mentioning, such as the strong gender association between starch and monosaccharides (not shown, see Paper IV). Men generally take larger helpings of bread and potatoes and women eat more fruit and vegetables. These gender differences are found in numerous studies and in addition to actual intake, they may also reflect social desires, as men are supposed to be more suspicious of vegetables whereas women are supposed to avoid starchy foods (Lupton 1996).

In Paper IV, both edentulous and dentate individuals were included and no analysis of the possible interaction between the intake of nutrients, dental status and dental caries could therefore be performed. There were also some methodological problems, as the registration of dental caries differed between the cohorts, especially in C-5, where the registration was made only based on radiographs. However, as a preliminary test, the model used in Paper IV was modified to include a dental caries variable (number of decayed teeth) and the population was altered to include only those with more than four teeth. A further adjustment was made regarding theory, as the dietary dimension could influence the caries rate and the caries rate

could influence the dental status. All three areas therefore had to be included within the same box. As a result, a box containing variables from both adulthood and old age was created (Figure 4).

The only dietary dimension that was associated with dental caries was sucrose-FA. Considering the fact that the associations between dental status and diet remained the same, the interpretation that the main explanation was chewing ability appears to be true. However, the association between sucrose and dental caries opens the way for other explanations. A high intake of sucrose increases the prevalence of dental caries, which then increases tooth losses (Fure 2003), which lead to chewing problems, which lead to a change in diet higher in sucrose, which then continues the circle. Morita et al. (2007) also found associations between the number of teeth and preference for sweet food. However, this can also be interpreted as meaning that a reduced chewing ability leads to both a higher sucrose intake and a higher rate of dental caries as a result of reduced oral clearance, for example. As both mechanisms are possible, the association between dental status and dental caries was interpreted as reciprocal.

Figure 4. Graphic interaction model displaying the conditional independent associations between dental status, intake of nutrients and dental caries. The arrows represent associations between an



explanatory and a response variable. Only statistically significant associations are included and only those associated with dental status, nutrient intake and dental caries. All individuals from the sample in Paper IV with five or more teeth are included.

In the Vipeholm Study, the circumstances such as salivary conditions also appeared to play a role in the caries process in addition to their food-eliminating role, but otherwise no analyses of the impact of oral function were made. The authors did, however, present a table relating to one of the different study groups (8-toffee-group, Gustafsson 1952) enabling an additional analysis of other factors. The table includes the number of periods with new

carious lesions, the number of periods with additional diet (8 toffees a day), age, the number of intact surfaces at the start of the study, intelligence group, diagnosis, problems when eating, tobacco habits and region of birth. These variables were used in a multiple linear regression model, with "periods with new carious lesions" as the dependent variable and excluding diagnosis and region of birth, and this resulted in a model with an adjusted R^2 of 0.55. In a backward stepwise procedure, the following variables were included in the final model; swallowing without chewing (partial correlation -0.66), grinding one's teeth (p.c. –0.53), feed (p.c. –0.50), putting things in one's mouth (p.c. 0.33), and age (p.c. –0.31). All variables in the final model apart from age were statistically significant. Some of these factors may influence "sugar time" but their high correlations may also indicate that they play a role by themselves in relation to dental caries. This indicates an association between oral function and dental caries, which was tested in Paper V.

Analyses of the association between oral function, oral sugar clearance and dental caries

In Paper V, a detailed cross-sectional study of the associations between oral function and dental caries was performed. Five different variable areas - oral function area, saliva area, oral sugar clearance area, caries-related oral microbiology area and caries-related status area – were acknowledged. After factor analyses within these areas, 20 different dimensions were included in the final analysis.

Two different models were tested on the basis of theoretical considerations. In Model 1, the prime interest was to analyse the associations between oral function and saliva as independent areas and oral sugar clearance as a dependent, while in Model 2, oral function, saliva, oral sugar clearance and caries-related microbiology were independent areas and dental caries was dependent (Figure 5).

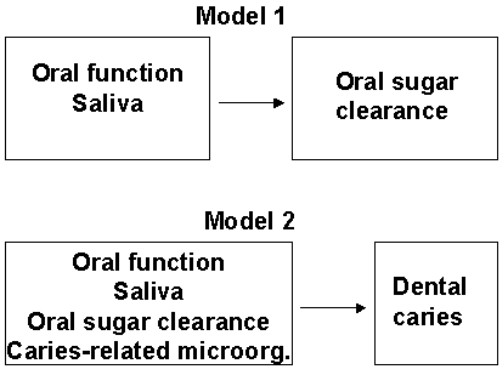


Figure 5. The areas used in the two regression models in Paper V.

The use of these models in regression analyses revealed that latent variables related to oral function played a substantial role in oral sugar clearance (Model 1). Both how well we chew, how we chew and how well the motoric ability is appeared to influence the clearance rate. Dental caries was in turn related to oral sugar clearance and to how fast we chew, for example (Model 2). These two ways of influencing dental caries could perhaps explain the results mentioned above regarding the Vipeholm Study. There are therefore results indicating that impaired oral function may be a cause of dental caries, at least among the elderly. This is in line with the findings reported by both Hase et al. (1987) and Lundgren et al. (1997), who found negative correlations between oral function and oral sugar clearance, as well as positive correlations between oral sugar clearance and dental caries.

The method used in Paper V does not allow us to study the interactions between variables. We can, however, re-analyse the material using the same methodology as in Paper IV, with oral gender in the first box, oral function and saliva in the next, oral sugar clearance in the third, caries-related microbiology in the fourth and dental caries in the last. The associations between some oral function variables and the latent variables related to oral sugar clearance, caries related microbiology and dental caries are presented in Table 5. The proportional number of decayed surfaces was statistically significantly associated with the time in the method used in Paper V but not in the present analysis, even if it is close. The reduced numbers of degrees of freedom are responsible for this, as there are now 19 variables for which the association is adjusted for in Table 5, but only three in Paper V. However, the partial correlation is the same ($r = 0.22$). The association between oral function and oral sugar clearance is now also changed, as the MA test is no longer statistically significantly associated and actually loses a large part of its correlation due to the adjustment of the other

variables. This underlines the importance of choosing and testing different models and of analysing differences between them in order to be able to inform theory. Table 5 also shows another feature that may be of importance and that is the number of variables that have associations around 0.20-0.25. As the statistical significance border in this study was about 0.22, a sample of 92 may have been too low and should perhaps have been about 120 instead to facilitate the interpretation of the results.

Table 5 can also be used to try to build new theories. The ecological plaque hypothesis (Marsh 1994) states that the plaque will be dominated by bacterial species that are favoured by the circumstances. The results indicate that *Candida albicans* is not sensitive to oral function. However, mutans streptococci is both related to the MA-test but in different directions, as *Streptococcus sobrinus* seems to be favoured by a lower ability and *Streptococcus mutans* by a higher ability. Lactobacilli are related to a slower and smaller opening when chewing. The findings relating to the mutans streptococci may be in line with the findings that the relative proportion of *Streptococcus sobrinus* increases in higher age groups (Fure 1998, Köhler & Persson 1991, Lundgren et al. 1996), but further studies are needed.

Table 5. Results relating to the associations between oral function dimensions and dimensions of oral sugar clearance, caries-related microbiology and dental caries. Partial correlation coefficients that were statistically significant ($p<0.05$) are presented without parentheses, while those with a p-value between 0.05-0.10 are presented with parentheses.

	Oral function dimension					
	Chewing efficiency-FA	Time chewing cycle-FA	Time opening phase-FA	Amplitude	Angle opening-FA	Motoric ability-FA
Oral sugar clearance-FA	-0.23				-0.32	
Candida-FA						(-0.21)
Sobrinus-FA				(0.22)	0.28	0.29
Mutans-FA		(0.22)				-0.29
Lactobacilli-FA			0.27	-0.28		
FS%-FA		-0.24	0.36			
DS%-FA		(0.22)				

Summary

The samples in the present studies appeared to be sufficiently large, to have sufficiently large variation and also to be representative of the elderly Swedish population and thereby represent no major threat to the trustworthiness. The statistical methods and the role of chance used in the studies appear to be well suited to answer the questions, as does the overall concept. The major problem of trustworthiness lies in the measurement of nutrient intake, or, more correctly, the ability to use interviews as measurements of actual intake. Nevertheless, the associations found between dental status and carbohydrate intake were in line with previous findings, relating to theoretical expectations and therefore appear meaningful. Good dental status appeared to facilitate the intake of primarily fruit and vegetables, while an impaired status increased the consumption of dairy products and food associated with sucrose. There were also data confirming that a higher intake of sucrose increases the prevalence of dental caries. Caries was also associated with oral function in a complex manner, where factors related to oral clearance appear to be especially important. As a result, a circular dependence between oral status, carbohydrate intake and dental caries appears to be trustworthy.

Conclusions

Analyses of the variation of intake of carbohydrates (Papers I and II)

- The intake of different carbohydrates was not associated with each other with the exception of different dietary fibre fractions.
- The change in the intake of carbohydrates between the elderly over time followed the overall changes in consumption among the general Swedish population.
- The longitudinal changes were minor, indicating that changes over time are largely period and cohort changes, although there were indications of some age effects.
- The intake of sucrose seems to be unreliably low.

Analysis of associations between carbohydrates (Paper III)

- The carbohydrate variables appeared to belong to a limited number of latent variables revealed by the factor analysis.
- The elderly populations could be clustered into meaningful samples using cluster analysis, revealing associations between carbohydrate intake and e.g. gender, social status and dental status.

Analysis of the interaction between the dietary intake and dental status (Paper IV)

- The results strongly indicated that dental status played an important role in the diet among the elderly, particularly when it came to carbohydrates.
- The results indicated that chewing ability was the main cause of the relationship between dental status and the diet.
- The association between sucrose intake and dental status could indicate a circular causal chain, in which dental caries has an impact on dental status.

Analysis of associations between oral function, oral sugar clearance and dental caries (Paper V)

- Oral sugar clearance appears to play a crucial role in dental caries among the elderly.
- Oral function may be both an effect of dental caries, due to tooth losses and a cause of it, due primarily to the effect on oral clearance.

Reflections on implications

The results of the studies presented in this thesis could be used to discuss at least five different research areas. They are:

- ✓ Nutritional epidemiology and the question of how to study complex matters such as dietary intake
- ✓ Public health and the question of whether dental status can improve health via the diet
- ✓ Food sociology and the influence of dental status on food selection by individuals and in society
- ✓ Dental service and how to examine and treat elderly patients with dental caries in terms of diet, oral function and sugar time
- ✓ Health and the capability of individuals to realise their vital aims in life depending on their dental status

Nutritional epidemiology

Baghurst et al. (1994) concluded that their results "highlight the need to consider relationships between nutrients … (in) nutritional epidemiology studies". Latent variable analysis (e.g. factor analysis) could be used more frequently in relation to nutrient intake, as the creation of conditionally independent variables facilitate analyses as the manifest nutrient variables have numerous dependences. Using a reduced number of variables can also considerably facilitate the analyses, as the number of test required diminishes. If the results of the present studies are also applicable to other studies of nutrient intake, latent variable analyses are definitely appropriate and perhaps even necessary when analysing nutrient intake and health effects. It may well be that analysing both ways, which is both an analysis based on manifest variables and an analysis based on latent variables, is a good way forward and would enable more well-elaborated conclusions.

Graphical Interaction Models are also an interesting development as they present theoretical assumptions in a straightforward manner and thereby facilitate the interpretation of the results and comparisons with other studies. The basic concept of conditional independence, which highlights the context of the variables, may be a good way forward, away from the variable-centred methods that attempt to remove and look away from circumstances. "… (U)nderstanding is gained by any process that locates a puzzling

phenomenon in a system of relationships" (Dean et al. 1993 p 32) and greater focus on methods that facilitates an understanding of this kind would be worthwhile.

Public health

Different diets are visible within Swedish society. In 1989, there were differences in diet among adults in different parts of Sweden, especially between the Stockholm region and northern Sweden (Becker, 1994). There were also differences between social classes, ages, different types of household and the sexes. Within Sweden, there are also differences in life expectancy and the distribution of diseases, between both regions and classes, and this could be related to the differences in diets (Lindberg & Rosén, 2000; National Board of Health and Welfare 2001; Baltzer & Melinder 2004).

Österberg et al. (2007 & 2008) have shown, dental health is clearly associated with survival. Nakanishi et al. (2005) also found that self-assessed masticatory disability was predictive of the 9-year mortality among elderly in Japan. However, the reason and whether or not preventive causes are included is not clear. The association remains also after adjusting for social factors, smoking and BMI, all three of which are related to dental status. Therefore may dental status differences be added to regional, class, age and gender differences that explain differences between individual survival and could perhaps be prevented.

Food sociology

Richard Lewontin (2001) proposes that, instead of using the word "adaptation" to describe the process of evolution, we should use the term "construction", as all life forms not only live passively in an environment but also construct their environment. He mentions four different ways this construction takes place and all of them could perhaps be applicable to food and humans:

1. By choosing our environment, not in the sense of the place in which we live, but more what in the place matters, in terms of food; i.e. what is food and what is not.
2. By altering the environment, not only to suit ourselves but also to suit others. Agriculture and fishing are obvious examples of the way humans adapt their environment and how we alter the lives of other species. Another example is using pre- and pro-biotics and thereby altering the gut environment by foods with or without microbes.

3. By modulating statistical properties of the environment. The most obvious one regarding humans and food are time and place averaging. We gather and store foods, like many other animals to average over time, but we also transport foods to average between places. We, like many others, store both nutrients and energy in our bodies to be able to average over time.
4. By creating special environment around and on our bodies. The intestinal tract is a special case, but special conditions are also created on our skin, allowing both our symbiotic fellows and us to protect us from the dry, wet, cold and/or warm air. This symbiosis also plays a part in our nutrition.

This can be used as one biological background to the sociology of food intake. However, in the mouth, there is even more that interacts between social forces and biological ones. Lupton (2000 p 17) refers to the omnivore's paradox, which states that humans lack a hereditary food preference, which makes us vulnerable to potentially poisonous foods and humans therefore base their food intake mainly on traditions passed down through generations. However, at the same time, humans are also interested in potential new foods and this is the paradox; omnivores are suspicious and conservative and at the same time also curious and exploring. The mouth has a special role to play within this paradox, the final place for acceptance or rejection, the gatekeeper role. Lupton (2000 p 18) also refers to Falk, who found three different levels of creating this gate; allowing food into the mouth, the intermediate judgement of taste and smell and the decision to chew and swallow.

Many of the results of the present studies are in line with these theories. The association between dental status and the intake of foods requiring chewing adds facts that underpin the assumptions relating to the mouth as a gatekeeper. However, the changes between cohorts that were independent of all the measured background factors imply that the "construction" of the diet plays a major role. Perhaps the improved dental status of the elderly in Sweden nowadays is facilitating the increasing intake of fruit and vegetables and the larger intake of bread and makes the dietary recommendations easier to adapt.

Dental service

The recommendation to reduce the intake of sucrose in order to avoid dental caries is in line with the findings in the present thesis. Even if the epidemiological evidence is weak in many studies and the use of fluoridated toothpaste has made the teeth less susceptible, sucrose intake was still associated with dental caries in the studies. The difficulties involved in

measuring the intake and the attenuation factor in dietary studies make it imperative not to jump to premature conclusions that the role of sucrose is diminishing. The dietary analysis of patients in the dental office is therefore still an important but difficult examination.

However the findings in both Paper IV and Paper V also show that there are other vital factors that influence the rate of dental caries and are seldom examined; they include aspects of oral function and oral sugar clearance. The importance of this was clearly seen in the Vipeholm material and it appears to be just as evident among the elderly today. Developing easy examinations and treatments applicable in ordinary dental work is a challenge for the future.

Health

The large variation in dietary intake even among the elderly with good dentition means that a good dental status is no guarantee of a good diet but an opportunity to be able to eat well. Nor is a poor dental status always associated with a poor diet and it is therefore more of a handicap than an absolute hindrance. According to some (Sen 1999), the focus of health should be to create capabilities to enable people to realise the essential goals in their lives, such as also enjoying food in old age. Lupton (1996) writes about how life becomes more and more oral, implying that the mouth plays an increasing role in our societies. The value of a nice smile with white teeth, combined with an ability to speak clearly and to be able to eat all kinds of food is increasing. This does not appear to require 32 healthy teeth but a healthy mouth appears to represent a good, valuable capability!

Glossary and abbreviations

Adjustment

In statistical terms, adjustment means seeing whether the association between two variables depends on another. For example, if you find that a low vegetable consumption is associated with a smaller height you may suspect that is associated with gender. Adjusting for gender means removing the influence of a variable. There may be four results, the associations remain the same, they disappear, they change direction or, if there was no association originally, an association may emerge. In our example, it probably changes direction and, instead of being a negative association, it becomes a positive one.

Age, period and cohort analysis

"Ageing is not immutable or fixed … but changes across and within cohorts as society changes. This is the basis of the identification of the factors of ageing, period and cohort effects. In analysis statistical confounding is the most problematic for analysis as there are only two measurements (age and time) but three factors (the identification problem). There are no foolproof techniques to solve the problems and therefore theoretical considerations are of need." (Dean et al. 1993, chapter 3)

ANOVA

Analysis of variance. The dependent variable is measured on the interval scale but at least one of the possible multiple independent variables is measured on a nominal or ordinal scale.

Area of variables

The area contains variables that are inter-related or dependent on each other. In cariology, the variables of decay (D), fillings (F) and tooth loss (M) are regarded as being related and are therefore included in the DMF index. A factor analysis to analyse interdependence can be an alternative to an index.

BMI

Body Mass Index. Calculated from the body weight (kg) divided by the height squared (m^2). According to the WHO, the definition of overweight in adults is a BMI ≥ 25, while obesity is defined as ≥ 30. (Eiben 2007) Although those definitions have been questioned in the elderly, especially the "overweight" range, the lower part of it seeming to mean low mortality in the over-70ties. (e.g. Dey & Steen 2001)

Bootstrapping

Bootstrapping is a modern, computer-intensive, general-purpose approach to statistical inference, falling within a broader class of resampling methods.

Bootstrapping is the practice of estimating the properties of an estimator (such as its variance) by measuring those properties when sampling from an approximating distribution.

It is often used as an alternative to inference based on parametric assumptions when those assumptions are in doubt. (Wikipedia)

Candida albicans *Candida albicans* is a diploid fungus (a form of yeast), which is capable of mating but not of meiosis and is a causal agent of opportunistic oral and genital infections in humans. (Wikipedia)

Carbohydrates Carbohydrates (from 'hydrates of carbon') or saccharides (Greek σάκχαρον meaning "sugar") are the most abundant of the four major classes of biomolecules, which also include proteins, lipids and nucleic acids. They perform numerous roles in living things, such as the storage and transport of energy (starch, glycogen) and structural components (cellulose in plants, chitin in animals). (Wikipedia)

Chewing efficiency The ability to chew food. Can be measured either as how long a person needs to chew an object before he/she is ready to swallow it, or how well an object can be chewed in a defined time space and then measuring this as the mean size of the remnants.

Cohort A cohort study or panel study is a form of longitudinal study used in medicine and social science. It is one type of study design and should be compared with a cross-sectional study.

A cohort is a group of people who share a common characteristic or experience within a defined period (e.g. are born, leave school, lose their job, are exposed to a drug or a vaccine, and so on). A group of people who were born on a day or in a particular period, say 1948, thus form a birth cohort. (Wikipedia)

Compounds Anything made by combining several things. The results of a factor analysis are called compounds in SPSS. However, they can also be called factors or dimensions.

Context 1/ The text in which a word or passage appears and which helps ascertain its meaning
2/ The surroundings, circumstances, environment, background or settings which determine, specify, or clarify the meaning of an event. In what context did your attack on him occur? "We had a pretty tense relationship at the time, and when he insulted me I snapped." (Wiktionary)

Control Controlling for something in an analysis is the same as adjusting for something (see adjustment).

Dental caries A disease that damages tooth structures, resulting in what is commonly called tooth decay or cavities, which are holes in the teeth. This damage first affects the hard tissues of the teeth (enamel, dentin and cement). As the destruction progresses, these tissues begin to break down and this can eventually lead to holes in the teeth. If left untreated, the disease can lead to pain, tooth loss, infection and, in severe cases, death. There is a long history of dental caries: over a million years ago, hominids such as Australopithecus suffered from cavities. However, the incidence of cavities was very low well into the paleolithic and mesolithic periods. The largest increases in the

prevalence of caries have been associated with dietary changes. Today, caries remains one of the most common diseases throughout the world. (Wikipedia)

Dental status A measure of the dentition. Can be measured in a number of different ways depending on the research question. The DMF-index is often used in dental caries studies, while the number of teeth and Eichner Index are used in studies focusing on chewing and dietary intake.

Dentures Dentures are prosthetic devices constructed to replace missing teeth, which are supported by the surrounding soft and hard tissues of the oral cavity. Conventional dentures are removable, but there are many different denture designs, some of which rely on bonding or clipping onto teeth or dental implants. (Wikipedia)

Dietary fibre Dietary fibres are the indigestible portion of plant foods that move food through the digestive system, absorbing water and easing defecation. Dietary fibre consists of non-starch polysaccharides such as cellulose and many other plant components such as dextrins, inulin, lignin, waxes, chitins, pectins, beta-glucans and oligosaccharides. The term "fibre" is something of a misnomer, since many of the so-called dietary fibres are not fibres at all. (Wikipedia)

Diet history method The method aims to define habitual intake during a specified period. Burke et al. (1947) introduced the method. Information includes usual meal pattern, estimates of portion sizes and frequency of consumption. The probing starts with open-ended questions about what is eaten first thing in the morning, and then goes more deeply into possible types of items. A carefully prepared form is often used to record the information and the interview lasts about 1-1.5 hour. (Rothenberg 1997)

Dimension A single aspect of a given thing or a construct whereby objects or individuals can be distinguished. The results of a factor analysis can be named factors, compounds or dimensions.

Direct oblimin A method for oblique (non-orthogonal) rotation. It simplifies the interpretation of the factors. Direct oblimin is used within factor analysis to obtain the final factor solution. (SPSS 10.0)

DMF Decayed – Missing – Filled. Index using teeth or surfaces of teeth to classify the dental status. A DMF-T value of 20 means that 20 teeth of 28 are decayed, filled or missing, while a DMF-S value of 20 means that 20 surfaces are decayed, filled or missing.

Dynamism Various treatments of dynamism can be found in the works of Baruch Spinoza and Henri Bergson and also, long before them, Parmenides, the Atomists and Plotinus. In more contemporary works, elements of dynamism also developed into process philosophy, via Alfred North Whitehead and others, as well as systems theory via Ludwig von

Bertalanffy and William Ross Ashby. Immanuel Kant was another philosopher who helped developed the theory of dynamism. More recently Colin Stott argues that many of the problems of traditional western philosophy arise from an unsustainably passive view of both matter and consciousness. His *A New Dynamism for Philosophy* seeks to reveal the potential of a re-invigorated dynamism to diagnose, address and propose accessible solutions to many of the subject's oldest questions. (Wikipedia)

Edentulous Edentulism is the condition of being toothless to at least some degree; it is the result of tooth loss. The loss of some teeth results in partial edentulism, while the loss of all the teeth results in complete edentulism. (Wikipedia). IIn this thesis, edentulous means complete edentulism.

Eichner Index This classification is based on existing natural tooth contact between the maxilla and mandible in the bilateral premolar and molar regions. These tooth contacts constitute four supporting zones and the presence or absence of tooth contact determines the classifications. Class A (3 subgroups: 1-3) represents contact in all four zones, class B (4 subgroups: 4-7) represents contact from 3 to 1 zone or only in the frontal region and class C (3 subgroups: 8-10) denotes the complete absence of tooth contact. A low score represents a well-preserved dental status. The Modified Eichner Index also includes teeth replaced by fixed prostheses. (Österberg 1990)

Eta^2 A measure of how much of the variance that is explained. It is found by dividing the between-groups sum of squares by the total sum of squares. (Spicer 2005, p 14)

Factor analysis A family of techniques, which is used to detect patterns in a set of variables, all of which are treated as dependent. The goal is to see whether it is possible to reduce the set to a smaller set of underlying factors. (Spicer 2005 p 181)
Factor analysis is often used in data reduction to identify a small number of factors that explain most of the variance observed in a much larger number of manifest variables. Factor analysis can also be used to generate hypotheses regarding causal mechanisms or to screen variables for subsequent analysis (for example, to identify collinearity prior to performing a linear regression analysis). (SPSS 10.0)
The unobserved variables that form the outcome of a factor analysis are called factors, compounds or dimensions.

FAO The Food and Agriculture Organisation of the United Nations (FAO) is a specialised agency of the United Nations that leads international efforts to defeat hunger. Serving both developed and developing countries, the FAO acts as a neutral forum where all nations meet as equals to negotiate agreements and debate policy. The FAO is also a source of knowledge and information and helps developing countries and countries in transition to modernise and improve their agriculture,

	forestry and fisheries practices, ensuring good nutrition and food security for all. (Wikipedia)
Food composition tables	Tables of the composition of different foods described as the amount of energy, nutrients and water in a specified amount of the food.
Graphical Interaction Model (GIM)	Aim "to make sense of possible patterns of multivariate interaction between several measured variables. … how graphs can portray multivariate interaction, response-explanatory models, such as regression, and further generalizations such as causal modelling." (Dean et al. 1993, p 160)
Hierarchical Cluster Analysis	This procedure attempts to identify relatively homogeneous groups of cases (or variables) based on selected characteristics, using an algorithm that starts with each case (or variable) in a separate cluster and combines clusters until only one is left. Example: Are there identifiable groups of television shows that attract similar audiences within each group? (SPSS 10.0)
K-Means Cluster Analysis	This procedure attempts to identify relatively homogeneous groups of cases based on selected characteristics, using an algorithm that can handle large numbers of cases. However, the algorithm requires you to specify the number of clusters. (SPSS 10.0)
Lactobacilli	Lactobacillus is a genus of Gram-positive facultative anaerobic or micro-aerophilic bacteria. They are a major part of the lactic acid bacteria group, named as such because most of its members convert lactose and other sugars to lactic acid. They are common and usually benign. Although considered beneficial, some lactobacillus species have been associated with dental caries. The lactobacillus count in saliva has been used as a "caries test" for many years. (Wikipedia)
Lactose	Lactose (also referred to as milk sugar) is a sugar, which is found most notably in milk. Lactose makes up around 2–8% of milk (by weight). The name comes from the Latin word for milk, plus the -ose ending used to name sugars. Its systematic name is β-D-galactopyranosyl-(1↔4)β-D-glucopyranose. (Wikipedia)
Latent variable	In statistics, latent variables (as opposed to observable variables) are variables that are not directly observed but are rather inferred (through a mathematical model) from other variables that are observed and directly measured. They are also sometimes known as hidden variables, model parameters, hypothetical variables or hypothetical constructs. One advantage of using latent variables is that this reduces the dimensionality of data. A large number of observable variables can be aggregated in a model to represent an underlying concept, making it easier for humans to understand the data. In this sense, they serve the same function as theories in general do in science. At the same time, latent variables link observable ("sub-symbolic") data in the real world, to symbolic data in the modelled world. (Wikipedia)

Mandibular movements	How the mandible (the lower jaw) moves in relation to the rest of the cranium when chewing. Includes speed, distance and angles.
Manifest variable	A directly observable variable as opposed to a latent variable.
MANOVA	Multivariate analysis of variance. It is distinctive in that it allows multiplicity of both independent and dependent variables. All dependent variables are measured on an interval scale, but some of the independent variables are measured on a nominal or ordinal scale. (Spicer 2005, p 153)
MA test	A family of several tests of motoric ability developed by Horst Landt. One test involves assembling two test-pieces in the mouth, including tests of recognition and handling the pieces, and this was used in Paper V. Other tests within the MA-test family are tests of stereognostic ability to perceive form and size.
Monosaccharides	Monosaccharides (from Greek monos: single, sacchar: sugar) are the most basic unit of carbohydrates. They consist of one sugar and are usually colourless, water-soluble, crystalline solids. Some monosaccharides have a sweet taste. Examples of monosaccharides include glucose (dextrose), fructose, galactose, xylose and ribose. Monosaccharides are the building blocks of disaccharides such as sucrose (common sugar) and polysaccharides (such as cellulose and starch). (Wikipedia)
MUFA	Mono-unsaturated fatty acids are fatty acids that have a single double bond in the fatty acid chain and all the carbon atoms in the chain are single-bonded. (Wikipedia)
Multinomial logistic regression	This technique is useful for situations in which you want to be able to classify subjects based on values of a set of predictor variables. This type of regression is similar to logistic regression, but it is more general because the dependent variable is not restricted to two categories. (SPSS 10.0)
Multiple regression	A data analysis technique that can be used to examine patterns of relationships between multiple independent variables and a single dependent. The technique can be elaborated to accommodate independent variables that are measured on scales other than an interval scale. (Spicer 2005, p 91)
Mutans streptococci	*S. mutans* and *S. sobrinus* play a major role in tooth decay, metabolising sucrose to lactic acid.[2] The acidic environment created in the mouth by this process is what causes the highly mineralised tooth enamel to be vulnerable to decay. *S. mutans* is one of a few specialised organisms equipped with receptors that help to improve adhesion to the surface of teeth. Sucrose is utilised by *S. mutans* to

	produce a sticky, extracellular, dextran-based polysaccharide that allows them to cohere to each other, forming plaque. (Wikipedia)
Oral sugar clearance	Clearance is the ability to eliminate the substance. Soluble substances introduced into the oral cavity are diluted by the freshly secreted saliva and subsequently swallowed. The reduction in the concentrations of substances in saliva with time is usually referred to as "oral clearance" or "salivary clearance". (Hase 1993)
PC-Kost	A computerised food composition table based on the Swedish National Food Administration food composition tables. Different versions exist.
Permutation test	A permutation test (also called a randomisation test, re-randomisation test, or an exact test) is a type of statistical significance test in which a reference distribution is obtained by calculating all the possible values of the test statistic under re-arrangements of the labels on the observed data points. In other words, the method by which treatments are allocated to subjects in an experimental design is mirrored in the analysis of that design. If the labels are exchangeable under the null hypothesis, the resulting tests yield exact significance levels. Confidence intervals can then be derived from the tests. The theory has evolved from the works of RA Fisher and EJG. Pitman in the 1930s. (Wikipedia)
Principal components analysis	A factor extraction method used to form uncorrelated linear combinations of the observed variables. The first component has maximum variance. Successive components explain progressively smaller portions of the variance and are all uncorrelated with each other. Principal components analysis is used to obtain the initial factor solution. (SPSS 10.0)
PUFA	Polyunsaturated Fatty Acids. A PUFA is a fatty acid in which more than one double bond exists within the representative molecule. In other words, the molecule has two or more points on its structure capable of supporting hydrogen atoms not currently part of the structure. Polyunsaturated fatty acids can assume a cis or trans conformation depending on the geometry of the double bond. (Wikipedia)
r^2/R^2	Coefficient of determination, a division of the regression sum of squares by the total sum of squares. A parallel to Eta^2 used in regression analysis. Adjusted R^2 is adjusted for the number of variables and sample size. (Spicer 2005, pp 23, 94)
Selspot ®	A company that produces equipment to measure the movements of objects in relation to others. Used in this thesis to measure the movements of the mandible in relation to the cranium.
SFA	Saturated Fatty Acids. Foods that contain a high proportion of saturated fat are butter, ghee, suet, tallow, lard, coconut oil, cottonseed

	oil and palm kernel oil, dairy products (especially cream and cheese), meat, chocolate and some prepared foods. There are several kinds of naturally occurring saturated fatty acids and the only difference is the number of carbon atoms - from 1 to 24. (Wikipedia)
Starch	Starch is by far the most consumed polysaccharide in the human diet. Traditional staple foods such as cereals, roots and tubers are the main source of dietary starch. Starch is often found in the fruit, seeds, rhizomes or tubers of plants and is the major source of energy in these food items. The major resources for starch production and consumption worldwide are rice, wheat, corn and potatoes. (Wikipedia)
Sucrose	Sucrose (common name: table sugar, also called saccharose) is a disaccharide of glucose and fructose. Its systematic name is α-D-glucopyranosyl- (1↔2)-β-D-fructofuranoside (ending in "oside", because it is not a reducing sugar). It is best known for its role in human nutrition and is formed by plants. (Wikipedia)
Sugar	Sugar is a class of edible crystalline substances, mainly sucrose, lactose and fructose. Human taste buds interpret its flavour as sweet. Sugar is a basic food carbohydrate, which comes primarily from sugar cane and from sugar beet, but it also appears in fruit, honey, sorghum, sugar maple (in maple syrup) and many other sources. It forms the main ingredient in much candy. The excessive consumption of sugar has been associated with increased incidences of type 2 diabetes, obesity and tooth decay. (Wikipedia)
Theoretical domain	A theoretical domain consists of units of analysis, environments within which the theory is supposed to hold, a substantive focus described by a set of concepts and a set of functional forms of relationships between concepts. A spanning set of concepts for a domain is a set in which all the relations of a domain can be stated. A causal locus in a domain is a set of variables, which occupy the same place in all statements of laws within the domain. The problem of measurements is to find observable variables, which occupy all the distinct causal loci of a domain. (Arthur L. Stinchcombe (1973). Theoretical Domains and Measurement: Part I. *Acta Sociologica* 16:3-12)
Typology	"Typology" literally means the study of types. (Wikipedia)
Varimax	An orthogonal rotation method that minimises the number of variables that have high loadings on each factor. It simplifies the interpretation of the factors. Varimax is used within factor analysis to obtain the final factor solution. (SPSS 10.0)
WHO	The World Health Organisation (WHO) is a specialised agency of the United Nations (UN) that acts as a co-ordinating authority on international public health. (Wikipedia)

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References

Ainamo A & Österberg T (1992). Changing demographic and oral disease patterns and treatment needs in the Scandinavian populations of old people. *Int Dent J* **42**:311-22

Alasuutari P (2004). Social theory & human reality. Sage Publications Ltd, Noida.

Aldenderfer M & Blashfield R (1984). Cluster analysis. Sage University paper series on Quantitative Applications in the Social Sciences, No.07-044. Beverly Hills and London.

Allen F & McMillan (2001). Food selection and perceptions of chewing ability following provision of implant and conventional prostheses in complete denture wearers. *Clin Oral Impl Res* **13**:320-6.

Asp N-G, Carlstedt I, Dahlqvist A, Johansson C-G & Paulsson M (1979). Dietary fibre. *Scand J Gastroent* **14 suppl 52**:128-37.

Baghurst K, Baghurst P & Record S (1994). Demographic and dietary profiles of high and low fat consumers in Australia. *J Epidemiol Community Health* **48**:26-32.

Baltzer M, Melinder K. Regionala matvanor och kostrelaterade dödsorsaker. Statens Folkhälsoinstitut 2004 (in Swedish). Statens folkhälsoinstitut. www.fhi.se.

Bailey RL, Ledikwe JH, Smiciklas-Wright H, Mitchell DC, Jensen GL (2004). Persistent oral health problems associated with comorbidity and impaired diet quality in older adults. *J Am Diet Assoc* **104**:1273-6.

Becker W (1994). Befolkningens kostvanor och näringsintag i Sverige 1989. Statens Livsmedelsverk, Uppsala. (in Swedish).

Becker W, Pearson M (2002). Riksmaten 1997-98. Statens Livsmedelsverk, Uppsala. (in Swedish).

Becker W, Enghardt H & Robertson A-K (1994). Kostundersökningar i Sverige 1950-1990. Statens Livsmedelsverk, Uppsala (in Swedish).

Bergeman C (1997). Aging: genetic and environmental influences. Sage publications, Thousand Oaks.

Bergh I, Steen G, Waern M, Johansson B, Oden A, Sjöström B, Steen B (2003). Pain and its relation to cognitive function and depressive symptoms: a Swedish population study of 70-year-old men and women. J Pain Symptom Manage **26**:903-12.

Bingham S (1987). The dietary assessment of individuals; methods, accuracy, new techniques and recommendations. *Nutr Abst Rev (Series A)* **57**:705-42.

Burke BS (1947). The dietary history as a tool in research. *J Am Diet Ass* **23**:1041-6.

Cummings JH, Stephen AM (2007). Carbohydrate terminology and classification. *Eur J Clin Nutr* **61(suppl 1)**:S5-S18.

Dahlqvist A & Asp N-G (1979). Carbohydrates. *Scand. J. Gastroent.* **14** suppl 52, 121-27.

Dean K ed (1993). Population health research – Linking theory and methods. Sage publications, Guildford.

Department of Health (1989). Report on Health and social subjects 37. Dietary sugars and human disease. Her Majesty's Stationery Office, London.

Dey DK, Steen B (2001). Overweight and obesity in the aged. In: Watson RR, ed. Handbook of Nutrition in the aged. 3rd edition. London, New York, Washington DC : CrC Press, Boca Raton; p 179-90.

Ebbeling C, Leidig M, Feldman H, Lovesky M, Ludwig D (2007). Effects of a low-glycemic load vs low-fat diet in obese young adults. *JAMA* **297**;2092-102.

Eiben G, Andersson CS, Rothenberg E, Sundh V, Steen B, Lissner L (2004). Secular trends in

diet among elderly Swedes – cohort comparisons over three decades. *Publ Health Nutr* **7**:637-44.
Eiben G (2007). Overweight and obesity in the young and old. Prevalence, prevention and eating behaviour. Thesis Göteborg University, Göteborg.
Elmståhl S, Birkhed D, Christiansson U & Steen B (1988). Intake of energy and nutrients before and after dental treatment in geriatric long-stay patients. *Gerodontics* **4**:6-12.
Eriksson BG, Mellström D & Svanborg A (1987). Medical-social intervention in a 70-year-old population. A general presentation of methodological experience. *Compr Gerontol C* **87**:49-56.
Firebaugh G (1997). Analyzing repeated surveys (Sage University ,Paper series on Quantitative Applications in the Social Sciences, No. 07-115). Thousand Oaks, CA: Sage.
Flint A, Moller B, Raben A, Pedersen D, Tetens I, Holst J, Astrup A (2004). The use of glycaemic index tables to predict glycaemic index of composite breakfast meals. *Brit J Nutr* **91**:979-89.
Fontijn-Tekamp FA, van Hof MA, Slagter AP, van Waas MAJ (1996). The state of dentition in relation to nutrition in elderly Europeans in the SENECA study of 1993. *Eur J Clin Nutr* **50:Suppl 2**:S117-22.
Foster-Powell K, Holt S, Brand Miller J (2002). International table of glycemic index and glycaemic load values: 2002. *Am J Clin Nutr* **76**:5-56.
Fure S & Zickert I (1990). Salivary conditions and cariogenic microorganisms in 55, 65, and 75-year-old Swedish individuals. Scand. J. Dent. Res. **98:**197-210.
Fure S (1998). Five-year incidence of caries, salivary and microbial conditions in 60-, 70- and 80-year-old Swedish individuals. *Caries Res* **32**:166-74.
Fure S (2003). Ten-year incidence of tooth loss and dental caries in elderly Swedish individuals. *Caries Res* **37**:462-9.
Geissler C & Bates J (1984). The nutritional effects of tooth loss. *Am J Clin* Nutr **39**:478-89
Gustafsson B (1952). Tandkaries och kolhydrater, Vipeholms-undersökningarna 1947-1951. *Svensk Tandläkare-Tidskrift* **45, suppl**.
Hase JC, Birkhed D, Grennert M-L, Steen B (1987). Salivary glucose clearance and related factors in elderly people. *Gerodontics* **3**:146-50.
Hase J C (1993). Influence of age and salivary secretion rate on oral sugar clearance. *Swed Dent J* **Suppl 89**.
Hugoson A, Koch G (2008). Thirty year trends in the prevalence and distribution of dental caries in Swedish adults (1973-2003). *Swed Dent J* **32**:57-68.
Hultén B, Bengtsson C & Isaksson B (1990). Some errors inherent in a longitudinal dietary survey revealed by the urine nitrogen test. *Eur J Clin Nutr* **44**:169-74.
Isaksson B (1980). Urinary nitrogen output as a validity test in dietary surveys. *Am J Clin Nutr* **33**:4-5.
Iversen G (1984). Bayesian statistical inference. Sage University paper series on Quantitative applications in the Social Sciences, 07-043. Newbury Park, CA: Sage.
James W P T (1989). Energy. In Nutrition in the elderly, ed Horowitz A, MacFayden D M, Munro H, Scrimshaw N S, Steen B & Williams T F. Oxford university press, Oxford.
Jenkins D, Kendall C, Augustin L, Franceschi S, Hamidi M, Marchine A, Jenkins A, Axelsen M (2002). Glycemic index: overview of implications in health and disease. *Am J Clin Nutr* **76(suppl)**:266S-73S.
Johansson L, Solvoll K, Bjørneboe G A & Drevon C (1998). Under- and overreporting of energy intake related to weight status and lifestyle in a nationwide sample. *Am J Clin Nutr.* **68**:266-74.
Karlsson S, Persson M, Carlsson GE (1991). Mandibular movement and velocity in relation to

state of dentition and age. *J Oral Rehab* **18**:1-8.
Karlsson R (2002). Svinn i storhushåll. Mängder, sammansättning och möjligheter att minska. www.infra.kth.se/fms/pdf/SvinniStorhushall.pdf. (English abstract)
Kiens B, Richter E (1996). Types of carbohydrates in an ordinary diet affect insulin action and muscle substrates in humans. *Am J Clin Nutr* **63**:47-53.
Kim JM, Stewart R, Prince M, Kim SW, Yang SJ, Shin IS, Yoon JS (2007). Dental health, nutritional status and recent-onset dementia in a Korean community population. *Int J Geriatr Psychiatry* **22**:850-5.
Kim J-O & Mueller C (1978a). Introduction to factor analysis: What it is and how to do it. Sage University paper series on quantitative applications in the social sciences, No.07-013. Beverly Hills and London.
Kim J-O & Mueller C (1978b). Factor analysis: Statistical methods and practical issues. (Sage University paper series on quantitative applications in the social sciences, No.07-014). Beverly Hills and London.
Kipnis V, Subar A, Midthune D, Freedman L, Ballard-Barbash R, Troiano R, Bingham S, Schoeller D, Schatzkin A, Carroll (2001). Structure of dietary measurement error: Results from the OPEN Biomarker Study. *Am J Epidemiol* **158**:14-21.
Krasse B (2001). The Vipeholm dental caries study: Recollections and reflections 50 years later. *J Dent Res* **80**:1785-8.
Köhler B, Persson M (1991). Salivary levels of mutans streptococci and lactobacilli in dentate 80- and 85-year-old Swedish men and women. *Community Dent Oral Epidemiol* **19**:352-6.
König K, Navia J (1995). Nutritional role of sugars in oral health. *Am J Clin Nutr* **62(suppl)**:275S-83S.
Lajous M, Boutron-Ruault MC, Fabre A, Clavel-Chapelon F, Romieu I (2008). Carbohydrate intake, glycaemic index, glycaemic load, and risk of postmenopausal breast cancer in a prospective study of French women. *Am J Clin Nutr* **87**:1384-91.
Lamy M, Mojon Ph, Kalykakis G, Legrand R, Butz-Jorgensen E (1999). Oral status and nutrition in the institutionalized elderly. *J Dent* **27**:443-8.
Landt H (1975). Oral ability to recognize forms and oral muscular coordination ability in dentulous young and elderly adults. *J Oral Rehabil* **2**:125-38.
Lindberg G & Rosén M (2000): Sveriges Nationalatlas - Folkhälsa och sjukvård (in Swedish). Almquist & Wiksell tryckeri, Uppsala.
Lingström P, Liljeberg H, Björck I & Birkhed D (2000). The relationship between plaque pH and glycemic index of various breads. *Caries Res* **34**:75-81.
Lingström P, van Houte J, Kashket S (2005). Food starches and dental caries. *Crit Rev Oral Biol Med* **1**1:366-80.
Livesey G, Smith T, Eggum B O, Tetens I H, Nyman M, Roberfroid M, Delzenne N, Schweitzer T F & Decombaz J (1995). Determination of digestible energy values and fermentabilities of dietary fibre supplements: a European interlaboratory study in vivo. *Br J Nutr* **74**:289-302.
Livingstone M B E, Prentice A M, Strain J J, Coward W A, Black A E, Barker M E, McKensy P G & Whitehead R G (1990). Accuracy of weighted dietary records in studies of diet and health. *Br Med J* **300**:708-12.
Livsmedelsverket (2007). Hur mycket socker äter vi? http://www.slv.se/templates/SLV_Page.aspx?id=14408&epslanguage=SV
Locker D, Matear D, Lawrence H (2002). General health status and changes in chewing ability in older Canadians over seven years. *J Public Health Dent* **62**:70-7.
Lundgren M, Emilson CG, Österberg T (1996). Caries prevalence and salivary and microbial conditions in 88-year-old Swedish dentate people. *Acta Odontol Scand* **54**:193-9.
Lundgren M, Birkhed D, Steen G, Emilson CG, Österberg T & Steen B (1997). Oral glucose

clearance in nonagenarians in relation to functional capacity, medication and oral variables. *Gerontology* **14**:17-27.
Lupton D (1996). Food, the Body and the Self. Sage, London.
Mann J, Cummings JH, Englyst HN, Key T, Liu S, Riccardi G, Summerbell C, Uauy R, van Dam RM, Venn B, Vorster HH, Wiseman M (2007). FAO/WHO scientific update on carbohydrates in human nutrition: conclusions. *Eur J Clin Nutr* **61(suppl 1)**:S132-7.
Marsh PD (1994). Microbial ecology of the dental plaque and its significance in health and disease. *Adv Dent Res* **8**:263-71.
Mack F, Mojon P, Budtz-Jorgensen E, Kocher T, Splieth C, Schwahn C, Bernhardt O, Gesch D, Kordass B, John U, Biffar R (2004). Caries and periodontal disease of the elderly in Pomerania, Germany: results of the study of health in Pomerania. *Gerontology* **21**:27-36.
McCullough M, Feskanich D, Stampfer M, Giovanucci E, Rimm E, Hu F, Spiegelman D, Hunter D, Colditz G, Willet W (2002). Diet quality and major chronic disease risk in men and women: moving toward improved dietary guidance. *Am J Clin Nutr* **76:**1261-71
McNeil N I (1988): Nutritional implications of human and mammalian large intestinal function. *Wld Rev Nutr Diet* **56**:1-42.
Mintz, S W (1985). Sweetness and power; the place of sugar in modern history. Viking, New York.
Mooney C, Duval R (1993). Bootstrapping: A nonparametric approach to statistical inference. Sage University paper series on Quantitative applications in the Social Sciences, 07-095. Newbury Park, CA: Sage.
Moreiras O, van Staveren W A, Amorim Cruz J A, Carbajal A, de Henauw S, Grunenberger F & Roszkowski W (1996). Longitudinal changes in the intake of energy and macronutrients of elderly Europeans. *Eur J Clin Nutr* **50**, Suppl 2:S67-S76.
Morita I, Nakagaki H, Kato K, Murakami T, Tsuboi S, Hayashizaki J, Toyama A, Hashimoto M, Simozato T, Morishita N, Kawanaga T, Igo J, Sheiham A (2007). Salutogenic factors that may enhance lifelong oral health in an elderly Japanese population. *Gerodontology* **24**:47-51.
Moynihan P (2005). The role of diet and nutrition in the etiology and prevention of oral diseases.*Bull World Health Org* **83**:694-9.
Mundy D (ed). A question of response rate (2002). *Science editor* **25**:25-26.
Murcott, A (1988). Sociological and social anthropological approaches to food and eating. *Wld Rev Nutr Diet* **55**:1-40.
National Board of Health and Welfare (2001). Folkhälsorapport 2001 (in Swedish) Http://www.sos.se/dokinfo2.asp?valPubl_id=2001-111-2.
Nordic Council of Ministers (2004). Nordic Nutrition Recommendations – Integrating nutrition and physical activity, 4th edition. NORD 2004:13. Copenhagen.
Nordström G, Lundgren B, Nilsson B, Steen B & Österlind PO (1988). Dietary habits in the eighth decade of life. *Comp Gerontol A* **2**:29-39.
Nordström G (2006). Tandläkarbesök och tandhälsa 1975-2005. Statistics Sweden. www.scb.se Nakanishi N, Fukuda H, Takatorige T, Tatara K (2005). Relationship between self-assesed
masticatory disability and 9-year mortality in a cohort of community-residing elderly people. *J Am Geriatr Soc* **53**:54-8.
Nowjack-Raymer RE, Sheiham A (2007). Numbers of natural teeth, diet, and nutritional status in US adults. *J Dent Res* **86**;1171-5.
Posner BM, Jette A, Smigelski C, Miller D & Mitchell P (1994). Nutritional risk in New England elders. *J Gerontol* **49**:M123-32.
Prentice AM, Davies HL, Black AE, Ashford J, Coward WA, Murgatroyd PR, Goldberg GR,

Sawyer M, Whitehead RG (1985). Unexpectedly low levels of energy expenditure in healthy women. *The Lancet* **1(8443)**:1419-22.
Quatromoni PA, Copenhafer DL, Demissie S, D'Agostino RB, O'Horo CE, Nam B-H, Millen BE (2002). The internal validity of the dietary pattern analysis. The Framingham nutrition studies. *J Epidemiol Community Health* **56**:381-8.
Rinder L, Roupe S, Steen B & Svanborg A. (1975). 70-year-old people in Gothenburg. A population study in an industrialized Swedish city. I. General presentation of the study. *Acta Med Scand* **198**:397-407.
Ritchie C, Joshipura K, Silliman R, Miller B, Douglas C (2000). Oral health problems and significant weight loss among community-dwelling older adults. *J Gerontology: Medical sciences* **55A**:M366-71.
Rothenberg E, Bosaeus I & Steen B (1996). Food habits and nutrient intake in three 70-year-old free-living populations in Gothenburg, Sweden. A 22-year cohort study. *Scand J Nutr* **40**:104-10.
Rothenberg E (1997). Nutrition in the elderly. Dietary intake and dietary assessment methods. Thesis Göteborg University, Göteborg.
Sandström B & Lindquist L (1987). The effect of different prosthetic restorations on the dietary selection in edentulous patients. *Acta Odontol Scand* **45**:423-8.
Schroll M, Steen B, Berg S, Heikkinen E & Viidik A (1993). NORA - Nordic research on aging. *Dan Med. Bull* **4**:618-24.
Sen A (1999). Development as freedom. Oxford University Press,
Sheiham A, Steele JG, Marcenes W, Lowe C, Finch S, Bates CJ, Prentice A, Walls AW (2001). The relationship among dental status, nutrient intake , and nutritional status in older people. *J Dent Res* **80**:408-13.
Spicer J (2005). Making sense of multivariate data analysis. Sage Publications, USA.
SPSS (2000), version 10 - 16, SPSS Inc. Chicago Illinois.
Sreebny LM (1982). Sugar availability, sugar consumption and dental caries. *Community Dentistry and Epidemiology* **10**:1-7.
Steen B, Isaksson B & Svanborg A (1977). Intake of energy and nutrients and meal habits in 70-year-old males and females in Gothenburg, Sweden. A population study. *Acta Med. Scand.* (Suppl.) **611**:39-86.
Steen B & Djurfeldt H (1993). The gerontological and geriatric population studies in Gothenburg, Sweden. *Z Gerontol.* **26**:163-9.
Subar A, Kipnis V, Troiano R, Midthune D, Schoeller D, Bingham S, Sharbaugh C, Trabulsi J, Runswick S, Ballard-Barbash R, Sunshine J, Schatzkin A (2003). *Am J Epidemiol* **158**:1-13.
Swedish Board of Agriculture (2007). Konsumtionen av livsmedel och dess näringsinnehåll. http://www.sjv.se/ statistik.htm.
Swedish National Food administration's food composition tables (in Swedish). Statens Livsmedelsverk 1986 (rättad upplaga 1988), Svenskt tryck, Stockholm 1988. (New editions 1996 and 2001).
Swedish National Food Administration (2000). "PC-kost", a software program, Uppsala.
Tacq J (1997). Multivariate analysis techniques in social science research. Sage Publications, Trowbridge, Wiltshire.
Tsuga K, Carlsson G, Österberg T & Karlsson S (1998). Self-assessed masticatory ability in relation to maximal bite force and dental state in 80-year-old subjects. *J Oral Rehab* **25**: 117-24.
Tzakis M, Kiliaridis S, Carlsson GE (1989). Effect of chewing training on masticatory efficiency. *Acta Odontol Scand* **47**:355-60.
Westergren A, Unosson M, Ohlsson O, Lorefält B, Hallberg I (2002). *Int J Nursing Studies*

39:341-51.
Willett W (2007). Confusion at the table: Can we trust that our food is healthy? In ed Shore D, The trust crisis in healthcare – Causes, consequences, and cures. Oxford University press, New York, USA.
Whittaker J (1993). Graphic Interaction Models: a new approach for statistical modelling. In Dean K ed. (1993) Population health research – Linking theory and methods. Sage publications, Guildford.
Woodward M, Walker ARP (1994). Sugar and dental caries: the evidence from 90 countries. *British Dent J* **176**:297-302.
Wolinsky F (1993). Age, period and cohort analyses of health-related behaviour. In Dean K ed (1993). Population health research – Linking theory and methods. Sage publications, Guildford.
Österberg T, Landt H (1976). Index för bettstatus, för epidemiologiska studier och kliniskt bruk. *Tandläkartidningen* **68**:1216-23. (in Swedish)
Österberg T & Steen B (1982). Relationship between dental state and dietary intake in 70-year-old males and females in Göteborg, Sweden: a population study. *J Oral Rehab*. **9**:509-21.
Österberg T, Mellström D & Sundh V (1990). Dental health and functional aging. *Dent Oral Epidemiol* **18**, 313-8.
Österberg T, Birkhed D, Johansson C & Svanborg A (1992). Longitudinal study of stimulated whole saliva in an elderly population. *Scand J Dent Res* **100**, 340-5.
Österberg T, Johanson C, Sundh V, Steen B, Birkhed D (2006). Seculat trends of dental status in five 70-year-old cohorts between 1971 and 2001. *Community Dent Oral Epidemiol* **34**:446-54.
Österberg T, Carlsson GE, Sundh V, Steen B (2007). Number of teeth – a predictor of mortality in the elderly? A population study in three Nordic localities. *Acta Odontol Scand* **65**:335-40.
Österberg T, Carlsson GE, Sundh V, Mellström D (2008). Number of teeth – a predictor of mortality in 70-year-old subjects. *Community Dent Oral Epidemiol* **36**:258-68.