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A 6-year longitudinal study of caries in teenagers and the effect of "dropouts" on the findings

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Objectives*:** To investigate attrition of subjects in a longitudinal study of caries. ***Design*:** A radiographic study of caries and caries-associated factors was carried out in subjects, initially aged 14 years, and followed-up for six years. Attrition of subjects occurred at the last stage of the study. ***Setting*:** A nationwide survey of subjects living in fishing, rural farming, and urban communities in Iceland. ***Sample and Methods*:** A sub-sample of the nationwide random sample comprising 150 subjects was investigated using bitewing radiographs and a structured questionnaire to determine caries-risk factors. Subjects were re-examined at 16 years and 20 years using the same methods. ***Results*:** Mean caries increment from 14-16 years was 3.0 lesions (1.5 lesions/subject/year) but reduced to 2.6 lesions (0.7 lesions/subject/year) by 20y. The proportion of subjects found to be caries-free at 14 years, 16 years and 20 years, was 29%, 17% and 10%, respectively. "Dropouts" from this study occurred mostly after 16 years. Analysis of subjects dropping out showed that they were least likely to be from the rural farming community but most likely from the fishing community. Those dropping out attended their dentist less frequently, had a higher consumption of carbonated drinks and a higher prevalence and incidence of caries by 16 years. ***Conclusions Subjects with high-risk behaviours, or residents in a fishing community were more likely to drop out of the study. Recognised advantages of conducting longitudinal studies of caries may, therefore, be lost.

Key words: Adolescents, caries risk factors, dental caries, Iceland, longitudinal study.

Introduction

The interplay of caries and cariogenic factors in the teenage years is often complex (Arnadottir *et al*., 1998) in comparison with the relatively simpler relationships found in younger subjects. This is largely because the lifestyle of teenagers is more complex than the lifestyle of children. Nevertheless, the basic caries-risk factors and the caries-preventive mechanisms remain the same. In investigations of caries, longitudinal studies have advantages over a series of cross-sectional studies in the same population (Burt, 1997). In particular, a more dynamic picture can emerge of the development of the disease over relatively short periods of time and it is possible to study the interplay of various risk and preventive factors with the developing disease (Holbrook *et al*., 1995). The risk in such studies is that subjects drop out before the completion of the study and this can then lead to a selection bias entering the analysis (Morrison *et al*., 1997). While several studies have investigated the effects of dropping out of treatments to reduce abuse of tobacco, alcohol or illegal substances (Cunradi *et al*., 2005), there have been relatively few studies of the effects of dropping out of longitudinal studies in dentistry. The reasons for dropping out of longitudinal dental studies appear to be related to poorer baseline dental status (Machiulskiene *et al*., 2002), lower dental awareness and even dissatisfaction with treatment (Kahl *et al*., 1995).

Several studies in Iceland have shown a positive correlation between dental caries and frequency of sugar consumption (Eggertsson *et al*., 1993; Saemundsson *et al*., 1992). In Iceland there is no water fluoridation; the concentration in drinking water is <0.04 ppm F^- (Arnadottir *et al*., 1998). From 1986 to 2000, a fortnightly, school-based, fluoride-rinsing programme (0.2% NaF) for 6-12-year-old children was in place during the school year (Arnadottir *et al*., 2004). Almost all children aged 6-17 years during the period of this study received fluoride varnish applications twice a year from their school or family dentist and 75% of all 12-year-old children had fissure sealants. A separate study conducted in 2000 found that only 80% of 16-17-year-old children had attended a dentist for examination in 18-month period (Águstsdóttir, 2001). Furthermore, 95% reported brushing their teeth regularly with a fluoride dentifrice (Bjarnason *et al*., 1993).

At the time of the present study, state-subsidised dental care in Iceland was available only up to the age of 17 years, except for special cases, and so it was thought worthwhile to assess the progression of caries in subjects over the period leading up to and shortly after the loss of state-subsidised dental care. For this, a longitudinal study was planned with subjects recruited from the three distinct types of community known to exist in the country. Farming districts, communities largely dependent on fishing and the main urban area in the country form these three communities and they were known to be distinct from one another with respect to employment, education and lifestyle These community types have already been shown also to experience different levels of caries (Elias-

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son, 2002). The aim was thus to study subjects resident in these three different communities who were initially aged 14 years and then follow them up for six years with respect to: (i) caries; (ii) dietary factors known to relate to caries; (iii) oral hygiene practices and (iv) pattern of dental attendance. Furthermore the effect on the overall findings of subjects dropping out of this longitudinal study was investigated.

Methods

In 1994, a stratified sample of 150 children was selected, distributed equally between the main urban area, a fishing town and a rural farming community. The 150 children were among 385 participants of mean age 14 years included in The Icelandic Nutrition Survey (INS) (Steingrímsdóttir *et al*., 1993). The total number of participants in this detailed national survey covering three age groups aged 10, 12 and 14 years was 1,166. The oldest age group was selected for this study because the aim was to observe changes in dental health in adolescents during the period immediately before and just after the removal of State-subsidised dental care. In the INS participants were selected randomly from 22 different schools where half of the schools were located in Reykjavík and surrounding areas and the other half were small town and country schools. In 1996, 123 of the 150 subjects (83%) from the sample (mean age then 16 years) returned for a second examination. In 2000 strenuous efforts were made to contact the sample for a follow-up study. These subjects had then been without state-subsidised dental care for three years. Use of the National Register available in Iceland, with permission, facilitated contact with the test subjects. In fact only 51 subjects (31%) from the original sample (then mean age 20 years) returned for the third examination. Permission for the study was obtained from the relevant national authorities: the National Ethics Committee, Data Protection Commission, Icelandic Radiation Protection Institute, with respect to radiographs and the Office of the Chief Medical Officer. Subjects, or their parents for subjects below 16 years of age, gave their informed consent.

Bitewing radiographs were taken using the long cone technique and size 2 Kodak Ekta–speed dental films using the same radiographic technique as Árnadóttir *et al*., (1998). Double films were used and the duplicates were given to the subject after the examination. All subjects were given a written comment along with their duplicate radiographs pointing out if their examination had suggested a need or an urgent need to seek dental care from their dental practitioner. Radiographs were read by one examiner (IBÁ) using a view box and magnification (LIC Dental, Enköping, Sweden). Caries was diagnosed using the criteria of Rimmer and Pitts (Rimmer and Pitts, 1991). Lesions were defined as decalcification on radiograph in the inner half of enamel or more and the incidence was calculated as a new lesion and/or a new filling at the next radiographic examination. The examiner was blinded as to the identity of the subjects and their place of residence. Each posterior tooth was scored and decayed and filled teeth for each subject were calculated. Intra-examiner reliability was assessed by replicate examinations of 10%, except for last visit where it was 20%, of the radiographs and computed by using the Kappa statistic.

To examine the frequency of sugar intake, subjects were asked at each examination to complete a one-page, multiple-choice questionnaire on the frequency of sugar consumption during the previous day, excluding weekend days. The sugar frequency multiple-choice questionnaire was developed with focus groups of the same age as the target population. The most frequently consumed sugar products mentioned by the focus groups were specified on the questionnaire by product names in an attempt to improve the accuracy of the questionnaire. Less-frequently mentioned products were not named and considered to be in the "other" category. Responses for the sugar-frequency questionnaire included the most often selected item of sugar- containing food consumed with meals and between meals. Similarly the consumption of sweetened beverages with meals and between meals was determined. In the questionnaire, meals were defined as breakfast, lunch and dinner, and the frequency as once, twice and three times or more, per day. Each instance of consumption of sucrose-containing foods or beverages was scored 1 and summed overall as well as separately for "during meals" and "between meals". In addition the frequency of use of sugar-free chewing-gum was assessed, as was the frequency of eating sweets and drinking sweetened beverages during the previous week. Adherence to the idea of restricting sweets to one day per week that was being promoted, by the health authorities at the time, was checked by a question.

A questionnaire related to dental health behaviours was also developed with focus groups of the same age as the target population. Participants completed the behavioural questionnaire with questions on: frequency of tooth brushing, flossing and frequency of dental visits. In order to gain an insight into the subjects' socio-economic background and lifestyle, questions were also asked about the average amount of pocket money per week and the average amount of money spent on sweets and sweetened beverages each week, number of siblings and age of mother, and participation in sports, music or arts.

Univariate, bivariate, and linear and logistic regression analyses were performed in 1994 and 1996. The dependent variable, caries status, was analyzed as both a continuous (number of surfaces per subject) and dichotomous (carious and caries free subjects) variable. In the univariate analysis, the dependent variable was dental caries prevalence on approximal surfaces at the different diagnostic levels of caries.

The bivariate analyses were performed to find any association between sugar consumption, the other covariates and the dependent variable that was defined as "with-caries" and "caries-free", controlling for place of residence. The caries-present and caries-free subjects were compared using the Kruskal-Wallis test. Variables other than the sugar exposure measures which were found to be associated with the outcome variables at a level of significance less than $p=0.20$ were included in linear and logistic regression analyses.

Subject attrition, especially for the final visit made the analysis of the data difficult and introduced a level

of uncertainty as to the reliability of the results. It was decided to investigate, as completely as possible, the data for those subjects that did not attend for examination in 2000 and to see what the effect of their absence had on the overall results. As two mean incidences of caries were available, one for the period 1994-6 and the other for 1996-2000, it was possible to extrapolate the mean incidences of caries onto the data available for those dropping out of the study. This was then used to prepare a model of the likely outcome of the prevalence data if those dropping out of the study had stayed in.

Results

Subjects were aged 14 years at the beginning of the study with participation rate of 98%, by 16 years it was 83.1% and at 20 years it had fallen to 34%. The annual rate of attrition was 5% between the first two visits but rose to 15% between the last two visits. Subjects in the rural farming community were best retained in the study .

There was good intra-examiner agreement (97%) for caries recording and a Kappa score of 0.80. The proportion of caries-free individuals was 28.7%, 17.0% and 9.8% for 14, 16 and 20-year-olds respectively. The mean DMFS score increased from 5.3 (sd 6.6) in 1994, to 8.3 (sd 9.5) in 1996, and then to 10.9 (sd 11.2) in 2000 (Table 1). Thus the mean caries increment was 1.5 new surfaces per subject per year the first two years, and 0.7 for the last four years. In 1996 the mean DMFS scores were 9.6 (sd 9.6) in the drop-out group, compared with 6.5 (sd 9.1) in those remaining in the study (Table 2). The mean caries increment for subjects that stayed in the study was 1.1 new lesions per person per year, and remained unchanged from 1994- 2000. While patterns of tooth brushing and use of dental floss seem to change little during the study period, there was a significant decline in the number of yearly dental visits and a significant increase in consumption of carbonated, largely cola-type, drinks. There was also a significant association of consumption of sweets between meals reported by subjects with caries **(**Arnadottir *et al*., 1998**).**

By the time the subjects were aged 20 years, there had been a considerable attrition in the study, which precluded regression analysis of the data. An analysis of those dropping out of the study was, however, interesting in itself as significantly more dropouts were originally residing in the fishing community ($p<0.02$). The drop-outs had a significantly lower frequency of dental visits (71%; 94% $p<0.02$) and significantly more consumed carbonated drinks more than three times per week by the age of 16 years than their peers who remained for the entire duration of the study (76%; 35%; $p<0.05$). Those subjects that dropped out of the study before 2000 were found, retrospectively, to have significantly higher DMFS scores already at baseline than those continuing in the study (t-test; $p<0.05$). This difference in caries prevalence was also significant at 16 years (t-test; $p<0.05$). Figure 1 shows the prevalence of caries recorded at each of the examinations. The figure shows the prevalence of caries for all subjects actually examined ("all") and for those who completed all three examinations ("participants 1994-2000"). Extrapolations were made to assess the effects of attrition in the overall study. One demonstrates the hypothetical development of caries if those dropping out of the study had experienced caries at the maximum rate observed in the study (1.5 new lesions/person/y) ("dropouts with max incidence"). A second line in the figure shows the hypothetical development of caries in the dropout group if they had experiences caries at the lowest incidence recorded in the study (0.7 new lesions/person/y) ("dropouts with min incidence").

The extrapolated lines show that if the dropouts had continued in the trial up to 2000 and had experienced the same incidence of caries as they did up to 1996 then there would have been a significantly greater incidence of caries (t-test; $p<0.05$) in the overall study by 2000 than was in fact measured in those participating in 2000. On the other hand, were those subjects that dropped out of the study to have experienced only the same incidence of caries as those remaining to 2000 then the overall prevalence of caries in the study would not have differed significantly from that recorded in 2000 (t-test; $p>0.05$).

Table 1. The number of subjects examined, mean DMFS (sd) and percentage caries free (CF) at age 14 (1994, 16 (1996) and 20 (2000)

Age (Year)	14 (1994)	16 (1996)	20 (2000)
N	148	123	51
Mean DMFS (sd)	5.3 (6.6)	8.3 (9.5)	10.9 (11.2)
% CF	28.7	17.0*	9.8*

χ^2 *($p<0.001$**)**

Table 2. Caries prevalence scores (DMFS) for the whole sample and separately for those continuing in the longitudinal study and those dropping out.

	1994	*1996*	*2000*
All subjects at each examination point	5.3 (6.6)	8.3 (9.5)	10.9 (11.2)
Subjects in study 1994-2000	4.1 (6.7)	6.5 (9.1)	10.9 (11.2)
Subjects dropping out before 2000	6.1 (6.4)	9.6 (9.6)	n/a

Mean DFS score (s.d.)

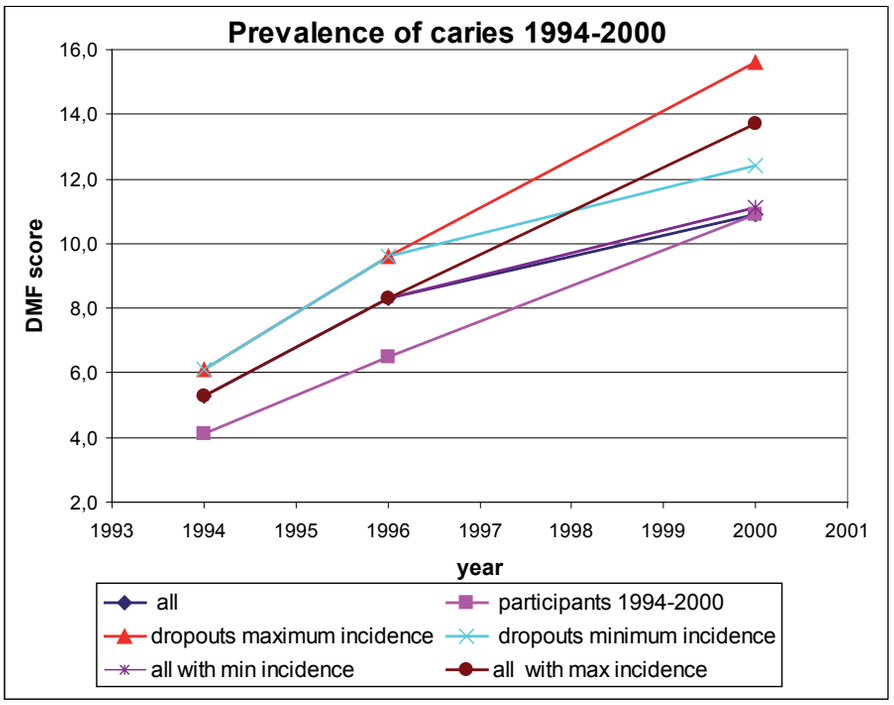

Figure 1. *The prevalence of caries in the study group 1994-2000 for all participants and separately for those participating and those dropping out of the study together with extrapolations of possible trends in caries prevalence for those dropping out after 1996.*

Discussion.

The background to this study was a longitudinal investigation of approximal caries in a sample of Icelandic teenagers over a six-year period. This is a time of considerable lifestyle-change for most young people. During the conduct of this longitudinal study it became apparent that subjects were failing to attend for planned reviews, particularly by the age of 20 years. Subjects dropped out of the study for a variety of reasons for example, because of work or further education but in the urban area there was also an apparent unwillingness to return for re-examination at 20 years of age. The age group chosen for the study and the 6-year study period was selected in order to cover the period during which state support for dental care in Iceland diminishes and then stops. Thus, the health authorities intend or assume that teenagers will have reached sufficient maturity by the age of 17 years to bear responsibility for their own dental health care and to finance any dental maintenance that may be required themselves. The results of this investigation show that this intention is not achieved and that teenagers are experiencing a period of active caries when State support for their dental care ceases. Those dropping out of the study could be assumed to have poorer dental health than those remaining in the study, as demonstrated by their baseline scores. On the other hand, no class-related dropout was observed as described by Machieulskiene and co-workers (Machiulskiene *et al*., 2002) and it was not until the subjects in the present study had left compulsory schooling that they began to drop out of the study.

Caries was assumed to develop largely on approximal surfaces, as more than 75% of teenagers of the age groups studied have signs of sealants on occlusal surfaces (Bjarnason *et al*., 1993) and there is a very low concentration of fluoride in all Icelandic drinking water. As approximal caries was assumed to be the most important lesion in this age group, and in order to reduce the considerable confounding effect of sealants, a radiographic study of caries was undertaken (Mejare *et al*., 1999). Diet has been shown to influence caries prevalence or incidence principally on smooth or approximal surfaces (Burt *et al*., 1988). Therefore, taking radiographs is the most appropriate diagnostic method to identify the high-caries-risk child and to evaluate the relationship between diet and approximal caries.

This longitudinal study showed a decrease in the rate of development of new lesions between 14 years and 20 years for the participants but the "dropouts" were, retrospectively, shown to have a higher rate of caries and it is unlikely that this would have reduced. As noted earlier this is likely to be the result from the best subgroup of subjects studied and the "dropouts" were likely to have experienced an even higher incidence of caries. The great increase in consumption of sweet carbonated drinks by subjects in this study and others in Iceland (Arnadottir *et al*., 1998) is the likely explanation of this high incidence of caries.

Differences in caries experiences between the three communities studied became less apparent by 16 years of age, as differences in lifestyle and dietary factors became less distinct. Several epidemiological studies of caries in Iceland (Möller,1985 Sæmundsson *et al*., 1992, Eliasson 2002) have shown this difference in caries prevalence with a higher prevalence in fishing communities, lower in farming communities and the urban capital area having prevalence values lying in between. In order to reduce

confounding factors only schools in one farming district and one fishing town were selected for this study and a group of similar number was selected from Reykjavík schools. All these schools were selected from those used in the original nutritional survey. From the earlier studies cited above, there was known to be a higher prevalence and incidence of caries in the fishing community, probably because teenagers living there have greater amounts of pocket money (Arnadottir *et al*., 1998) and a large number of places where candy and sweet, carbonated drinks can be purchased. The opposite is the case in the farming community and the urban community lies somewhere in between in most of the factors measured in this study (Arnadottir *et al*., 1998; Holbrook *et al*., 1995). It could have been speculated that children in fishing communities would eat more fish and thus have a higher intake of fluoride than other subjects in the study. However, fluoride is present in fish bones rather than the flesh and these bones are not eaten. This point has been discussed in detail in a study of urinary excretion of fluoride carried out in a multi-centre investigation of children in six European towns, including Reykjavík that was carried out as part of the FLINT project of fluoride ingestion from toothpaste (Ketley *et al*., 2004)

In 1994, between-meal snacking was found to be the most important factor in explaining differences in caries scores (Arnadottir *et al*., 1998). Although recall bias is a threat to study results and subjects have a tendency to underestimate sugar exposure, several Icelandic studies using similar methodology to that adopted here have shown frequency of sugar consumption to be a useful measure of caries risk (Arnadottir *et al*., 1998; Eggertsson *et al*., 1993).

Arnadottir *et al*. (1998) have shown that the most significant variable for subjects with and without caries was the *frequency* of eating sweets. For subjects in the present study at the baseline of 14 years it was found that 50% of those subjects who ate sweets once a week or less were caries-free compared with 13.5% of those eating sweets at least once a day ($p<0.05$) (Arnadottir *et al*., 1998).

It was found that subjects with high frequency of missed/cancelled appointments during age 12-18 years had a lower response rate than the rest of the group. This may indicate that non-utilization behaviour in the present study was under-reported. Males with non-attendance behaviour during the ages 12-18 years apparently have not changed their behaviour at the age of 23 years (Skaret *et al*., 2003). Although there were fewer males continuing in the present study up to the age of 20 years no significant gender difference was noted. Gender-based differences in attendance patterns may, however, provide useful information for future planning of possible interventions aimed at reducing the number of subjects failing to attend for dental care.

Several reasons for dropping out of this study became apparent especially at the age of 20 years. This included subjects working, especially in the fishing community and not being available for inspection. Some subjects had moved away from home for further education and could not attend for one of the inspections. There was also a clear reluctance to attend by the time the subject was 20 years and this makes data collection in this age group difficult. When the data were analysed again, with the data from 1994 and 1996, caries incidences were calculated separately for those subjects remaining in the study until 20 years and for those dropping out. The projection of caries shown in Fig. 1 shows that if this significant difference in caries had been maintained and the subjects remained in the study, there would have been a significantly higher overall caries score by 20 years ($p< 0.05$). Only if the caries incidence had been as low for the dropouts as for the remaining participants would the mean caries score have been similar to that actually observed in the study. All measures of caries risk factors for the subjects that dropped out of the study suggest that such a reduction in caries incidence would be unlikely. Therefore, by dropping out of the study these subjects significantly skewed the results of the study and made the progression of caries appear less dramatic than it probably really was and suggest that caries incidence actually reduced between 16 and 20 years, which is unlikely in the absence of any extra preventive effort.

The loss of subjects from longitudinal studies is a problem that often counter-balances the value of being able to follow the interplay between disease-modulating factors and disease incidence over time. In the present study those dropping out between 16 years and 20 years appeared to be those subjects that, at the age of 16 y were already with the worst dental health and at most risk of continuing to develop most caries. The results of the study would, therefore, underestimate the degree of dental disease in the community. This could in turn lead to untimely changes in provision of dental health care to the community that are not justified by the real clinical situation. The reasons for unwillingness to participate in a study such as this merit further investigation.

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