

Dental erosion and soft drink consumption in Swedish children and adolescents and the development of a simplified erosion partial recording system

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Abstract

© The aims of this study were to investigate the prevalence of dental erosion among Swedish children and adolescents and to examine its relation to soft drink consumption. It was hypothesized that the prevalence of dental erosion would be higher in boys than girls, that it would show a correlation with soft drink consumption and that a further simplification of a previously-used partial recording screening system for dental erosion would have an acceptable sensitivity and specificity.

801 individuals were invited to participate, of whom 609 (75%) accepted. 135 were 5-6 years, 227 were 13-14 years, and 247 were 18-19 years old. A questionnaire survey of each individual's soft drink consumption habits, in addition to a clinical examination, were performed.

Severe erosion extending into dentine on one or more maxillary anterior teeth/ molars was found to be 13.3% in the 5-6 group, 11.9% in 13-14 group and 22.3% in 18-19 group. The total prevalence for all age groups was 16.4%. The severity of erosion was highest among 18-19 year-old boys, 34.4 % of whom exhibited one or more teeth with severe erosive damage while none of the girls did so. Soft drink consumption was significantly correlated with severity of dental erosion in the 18-19 and 13-14 groups but not in the 5-6 years old group. A simplified erosion partial recording system (SEPRS) using 4 (permanent) or 6 (primary) surfaces as markers showed excellent sensitivity (100%/100%, respectively) and specificity (98%/100%, respectively) in relation to scoring of all maxillary canines/incisors and first permanent/all primary molars.

In view of the high prevalence of dental erosion and soft drink consumption among Swedish children and adolescents reported here, there is clearly a need for a national epidemiological registration system as well as for community-based preventive programs to be implemented. The hypothesis that dental erosion would be higher in boys than girls and that it would show a correlation with soft drink intake was confirmed.

Key words

Adolescents, beverages, child, index, partial recording, prevalence, tooth erosion

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Dental erosion och dryckeskonsumtion hos svenska barn och ungdomar samt utveckling av ett förenklat partiellt screening-system för erosion

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Sammanfattning

☉ Syftet med denna studie var att undersöka förekomsten av dental erosion hos svenska barn och ungdomar samt att relatera denna till dryckeskonsumtion. Hypotesen var att förekomsten av erosion var högre hos pojkar än hos flickor, att den var korrelerad till dryckeskonsumtion och att en ytterligare förenkling av ett tidigare utvecklat partiellt screening-system för dental erosion skulle uppvisa en godtagbar sensitivitet och specificitet.

801 individer erbjöds medverka i studien, av vilka 609 (75%) accepterade. 135 var 5-6 år, 227 var 13-14 år, och 247 var 18-19 år. Den kliniska undersökningen kompletterades med en intervju om varje individs konsumtionsvanor av drycker.

Hos 13,3% av 5-6 åringar, 11,9% av 13-14 åringar och 22,3% av 18-19 åringar registrerades grav erosion in i dentin på minst en tand i överkäksfronten eller på sexårständer/mjölkmolarer. Förekomsten för hela gruppen var 16,4%. Förekomsten var högst hos 18-19-åriga pojkar där 34,4% uppvisade minst en gravt erosionskadad tand, vilket ingen av flickorna gjorde. Dryckeskonsumtionen var signifikant korrelerad till svårighetsgraden av erosion i 18-19 års gruppen och i 13-14 års gruppen men inte i 5-6 års gruppen. Det förenklade screeningsystemet för erosion (SEPRS), där 4 (permanent) eller 6 (primära) tandtyper användes som markörer, uppvisade en utmärkt sensitivitet (100%/100%) och specificitet (98%/100%) i jämförelse med en fullständig registrering av alla tänder i överkäksfronten och alla sexårständer/mjölkmolarer.

Mot bakgrund av den höga prevalensen av dental erosion och dryckeskonsumtion hos svenska barn och ungdomar, finns ett uppenbart behov av att införa nationella epidemiologiska registreringar, liksom av att införa landsomfattande preventionsprogram. Hypotesen att dental erosion var vanligare hos pojkar än hos flickor och att förekomsten av erosion var korrelerad till dryckeskonsumtion uppfylldes

Introduction

The terms erosion, attrition, and abrasion have widespread acceptance as descriptors of tooth wear. In short, dental erosion implies acid-induced wear of dental hard tissue, attrition wear by tooth-to-tooth contact and abrasion wear by foreign objects (eg. toothbrush). Recent studies in different countries have shown that dental erosion is common among children and adolescents but that its prevalence varies. Since studies vary in cohort composition such as socioeconomic background and age, investigation methods, investigators and indices, their results are difficult to compare. Among children aged 5-6 years, prevalence figures of dental erosion with dentine involvement ranges from 21-34% (3, 9, 10, 14) and in 13-14 years from 13-53% (3, 6, 11, 13, 23). There are no reports on adolescents aged 18-19 years, but among 20 year-old Saudi men, the prevalence of dental erosion with dentine involvement was 16% while the corresponding figure for 15-17 year old Danish boys and girls was 1.6% (20, 22). In 15 year old Dutch children, 24% exhibited deep enamel or dentin erosion (1). In one study, no significant difference in prevalence between 11-14 year-old male and female children was found (7), but other studies have reported gender differences in the prevalence of dental erosion as well as in soft drink consumption. In this regard, it has been reported that boys had significantly more dental erosion than girls, and that male gender, white children and social deprivation were significantly associated with erosion (1, 11, 25).

Several reports have shown that the consumption of carbonated drinks is higher among teenage boys compared to girls (2, 5, 24). It has also been reported that dental erosion has a clear association with consumption of soft drinks. In a group of young Saudi men it was found that a higher intake of cola-type drinks was more common in a high- than in a low-erosion group (253 l/yr and 140 l/yr, respectively) (19). In Icelandic adolescents (19-22 years) significantly higher erosion scores were found in the molars of subjects drinking more than 1 l of carbonated drinks per week than those who did not (16). In a group of 1149 British 12 year-olds, it was found that high consumption of carbonated drinks increased the odds for erosion being present by more than two-and-a-half times (11).

In the clinical situation grading of erosion is often overlooked and difficult to perform, especially at an early stage, and many scales and systems available for scoring dental erosion are time consuming and complicated to use. In epidemiological studies there

is a need for a simple screening system with a high degree of accuracy.

The aim of the present study was to investigate the prevalence of dental erosion among Swedish children and adolescents and to examine its relation to soft drink consumption. It was hypothesised that the prevalence of dental erosion would be higher in boys than girls and that it would show a correlation with soft drink consumption. A further hypothesis was that a reduced number of dental marker surfaces would be representative of an individual's severity of dental erosion.

Material and methods

Patient selection

A total of 1580 children and adolescents aged 5-6, 13-14 and 18-19 years at the Public Dental Health Service in Nora and Storå, County Council of Örebro, Sweden were enrolled in the study. Due to time constraints at the clinic, only a limited number of appointments could be allocated for the study and a total of 801 patients were given appointments in consecutive order from the computerised recall system at the Public Dental Health Service during the study period in 2005-2007. All data collection took place during their regular dental health examinations. 609 children (75%) accepted to participate in the study, of whom 135 were aged 5-6 years, 227 were 13-14 years, and 247 were 18-19 years old. 51% were males.

The regular dental health examination followed a routine protocol and radiographs were taken on individual indications. In addition, the severity of dental erosion was recorded on maxillary canines, lateral and central incisors and the presence of cuppings were recorded on first permanent molars/all primary molars.

Clinical examination

The grading of dental erosion on maxillary anterior teeth was performed according to a scale and a system developed by *Johansson et al.* (17) (Table 1) and a separate scale was constructed and used for recording molar cuppings (Table 2). Before the study, calibration on the grading of dental erosion was performed between the investigator (AH) and a more experienced researcher in terms of clinical recording of dental erosion (AKJ). Intra-examiner concordance in the use of the scales for grading erosion and cuppings was tested by the examiner (AH) performing two successive blind assessments after an interval of 2-6 weeks in 10 patients aged 5-6 years

© **Table 1.** Ordinal scale used for grading severity of dental erosion on buccal and lingual surfaces of maxillary anterior teeth (17).

Grade	Criteria
0	No visible changes, developmental structures remain, macro-morphology intact.
1	Smoothened enamel, developmental structures have totally or partially vanished. Enamel surface is shiny, matt, irregular, "melted", rounded or flat, macro-morphology generally intact.
2	Enamel surface as described in grade 1. Macro-morphology clearly changed, facetting or concavity formation within the enamel, no dentinal exposure.
3	Enamel surface as described in grades 1 and 2. Macro-morphology greatly changed (close to dentinal exposure of large surfaces) or dentin surface exposed by $\leq 1/3$.
4	Enamel surface as described in grades 1, 2 and 3. Dentin surface exposed by $>1/3$ or pulp visible through the dentin.

Note: Approximal erosion and presence of "shoulder" should be recorded.

© **Table 2.** Ordinal scale used for grading cuppings on occlusal surfaces of first permanent molars and primary molars.

Grade	Criteria
0	No cupping/intact cusp tip
1	Rounded cusp tip*
2	Cupping ≤ 1 mm
3	Cupping > 1 mm
4	Fused cuppings: at least two cuppings are fused together on the same tooth

*Changed morphology compared to the assumed original anatomy at the time of eruption

(primary teeth) and in 24 patient aged 13-14 years/18-19 years (permanent teeth). All 6 maxillary anterior teeth (buccal and palatal surfaces) were graded for severity of erosion and all first permanent and all primary molars were graded for cuppings.

The highest scores from the recordings of maxillary anterior tooth erosion (Table 1) and cuppings on first molars/primary molars (Table 2) were used to determine the total prevalence of erosion and transformed to the scale: i) No erosion (score 0); ii) mild erosion (score 1); iii) moderate erosion (score 2); iv) severe erosion (score 3); v) very severe erosion (score 4). This means that to qualify for a score 1 (mild erosion), 2 (moderate erosion) or 3 (severe

erosion), maximum score from the grading of all the maxillary anterior teeth (Table 1) and from grading molar cuppings (Table 2) had to be 1, 2 or 3 respectively, with no exceeding score on any tooth surface. Qualifying for score 4 (very severe erosion) indicates that there was at least one tooth surface on the maxillary anterior teeth graded with 4 (Table 1) or a molar occlusal surface with cupping score 4 (Table 2).

In addition, buccal cervical defects were recorded for all teeth according to Johansson (17) and only defects showing clear demarcation were recorded. One examiner (AH) performed all the clinical examinations.

Questionnaire

During the clinic visit, a questionnaire was completed through an interview by a specially trained dental assistant. The questionnaire enquired in detail drinking habits, type of drinks and amount and frequency of consumption. Carbonated soft drinks were recorded separately from all soft drinks which also included juice, still drinks and sport drinks. The additional time needed for the extended examination and interview was approximately 15 minutes.

If there was a diagnosis of erosion, the patient was informed about the condition and preventive and/or restorative measures were carried out when indicated. The clinical examiner was blinded to all information obtained from the questionnaire.

Approval from the Regional Ethical Review Board, Uppsala, Sweden was obtained prior to the start of the study.

Statistical analysis

A simplified erosion partial recording system (SE-PRS) using different marker surfaces was developed and evaluated. The final model comprised highest erosion scores from the palatal surfaces of central maxillary incisors (according to Table 1) (tooth numbers 11/21) and from cupping scores (according to Table 2) of mandibular first permanent molars (tooth numbers 36/46) (4 surfaces in all). The final selection from the primary teeth comprised the highest scores from the palatal surfaces on maxillary central incisors (tooth numbers 51/61) and all 4 primary first molars (totally 6 surfaces). The sensitivity and specificity for the 4 and 6 selected surfaces from the permanent and primary teeth, respectively, were calculated in relation to the scores on all the graded permanent (16 surfaces) and primary (20 surfaces) maxillary anterior (buccal and palatal surfaces) and molar (occlusal surfaces) teeth.

Differences between the groups were tested by the Mann-Whitney U-Test. Pearson correlation analysis was used for assessing the association between soft drink intake and severity of dental erosion as well as between buccal cervical defects/cupplings and erosion scores. $P < 0.05$ were considered statistically significant. Sensitivity and specificity was calculated by cross-tabulation and standard statistical procedures. All analyses were performed on a Personal Computer using the Statistical Product and Service Solutions (SPSS, Release 15).

Results

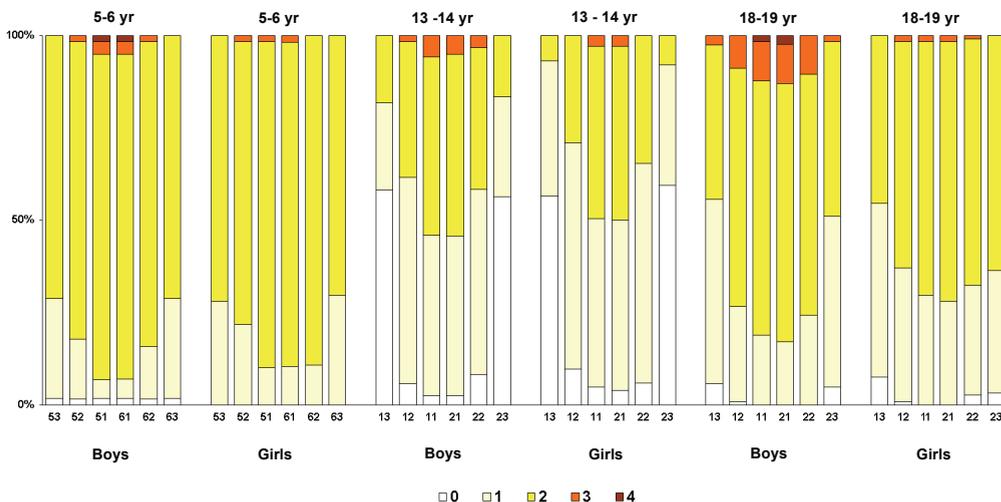
Intraexaminer concordance for the severity of maxillary anterior erosion and cupplings were for permanent teeth 71% and 80%, respectively. For the primary teeth, the corresponding figures were 64% and 76%. In cases of disagreement, the deviation was one scale unit except in two surfaces where it was two scale units.

The dropout of 192 patients were distributed as follows: 41 never showed up for their appointment; 103 did not accept to participate or failed to cooperate due to reasons such as disability to cooperate during the clinical examination, or occasionally language problems and/or functional disorders; and 48 failed to return the signed consent and were therefore excluded from the study.

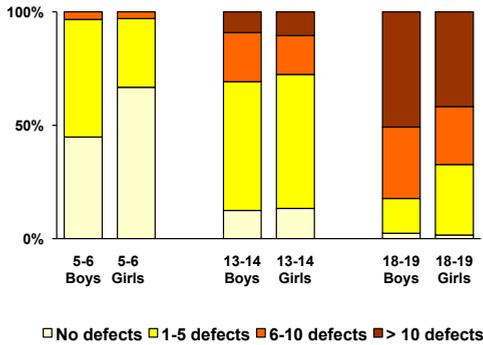
Percentage distribution of erosion grades on all graded anterior teeth in the different age groups are shown in Figure 1. Grade 3 or 4 erosion (Table 1) was found only on palatal surfaces in all age groups. Using the highest erosion score per individual, no gender differences were found in age groups 5-6 and 13-14, while in age group 18-19 boys exhibited significantly higher erosion ($P = 0.002$). The severity of erosion on anterior teeth was highest among 18-19 year-old boys, 15% of whom exhibited one or more anterior teeth with grade 3 or 4 erosion.

The distribution of cervical defects (total number/individual) and cupplings (highest score/individual) on all primary molars and on all first permanent molars are shown in Figures 2 and 3. In age groups 5-6 and 18-19, boys had significantly more cervical defects than girls ($P = 0.019$ and $P = 0.039$, respectively), but not in the 13-14 group. The most common site for cervical defects was on the right maxillary incisor (tooth number 11) in both 13-14 and 18-19 year group. As regards cupplings, boys had significantly higher scores in age groups 13-14 and 18-19 ($P = 0.02$ and $P = 0.01$, respectively), but not in age group 5-6. The most frequently found site for cupplings was on the mandibular first molar in the permanent teeth and first maxillary molar in the primary teeth. There was a statistically significant correlation between mean erosion scores on maxillary anterior permanent te-

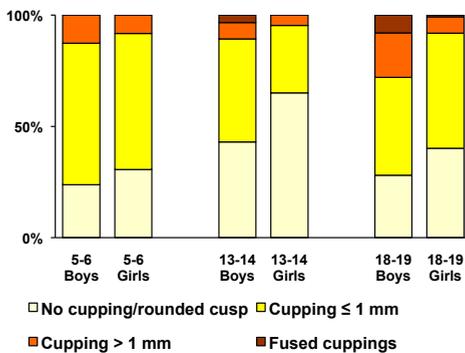
© Figure 1. Percentage distribution of erosion grades (Table 1) on buccal and lingual surfaces of primary (tooth numbers 53-63, age group 5-6 years) and permanent (tooth numbers 13-23, age group 13-14 and 18-19 years) maxillary anterior teeth, in boys and girls.



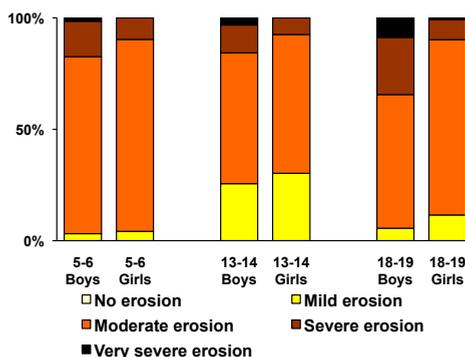
© **Figure 2.** Percentage distribution of number of cervical defects/individual on primary teeth in age group 5-6 years and permanent teeth in age groups 13-14 years and 18-19 years, in boys and girls.



© **Figure 3.** Percentage distribution of highest cupping grade/individual on primary molars (Table 2) in age group 5-6 years and first permanent molars in age groups 13-14 years and 18-19 years, in boys and girls.



© **Figure 4.** Percentage distribution of combined scores of highest occlusal wear/molar cuppings score and erosion grade on anterior teeth/individual (Tables 1 and 2), in the three groups, in boys and girls.



eth and number of cuppings ($r=0.47, P=0.001$) and buccal cervical defects ($r=0.36, P=0.001$) (groups 13-14 years and 18-19 years) but not so in primary teeth (group 5-6 years).

By using the SEPRS, the prevalence of severe/very severe erosion as obtained from the combined highest score of recorded dental erosion, on maxillary central incisors (tooth number 11 and 21) on palatal surfaces, and cuppings on mandibular first permanent molars (tooth number 36 and 46), was 11.9% (27 of 227 individuals) in the 13-14 group and 22.3% (55 of 247 individuals) in the 18-19 group. The corresponding figure for the 5-6 group (first primary molars, tooth numbers 51, 61) was 13.3% (18 of 135 individuals). The total prevalence among all age groups was 16.4% (100 of 609 individuals) and was highest in boys aged 18-19 years (34.4%; 43 of 125 individuals) (Fig. 4). Differences between boys and girls were only significant in the 18-19 group ($P=0.001$). If score 2 (moderate erosion) was included in the combined scoring of erosion and cuppings, the prevalence increased to 96.3% in the 5-6 group, 72.2% in the 13-14 group and to 91.5% in the 18-19 group.

Consumption of soft drinks was significantly higher among boys compared to girls in age groups 13-14 and 18-19, but not in age group 5-6 (Table 3).

There was a significant correlation between reported soft drink consumption and severity of dental erosion in the 18-19 group ($r=0.36, p=0.001$) and in the 13-14 group ($r=0.14, p=0.04$), but not in the 5-6 group.

As regards SEPRS, by using the combined highest scores for the palatal surfaces of maxillary central in-

© **Table 3** Mean soft drink (\pm SD) consumption (litres per year) for carbonated and all soft drinks in the 3 groups. P denotes differences between boys and girls.

Age group		Carbonated soft drinks	P	All soft drinks*	P
5-6	Boys	10.5 \pm 11.8	NS	50.3 \pm 42.4	NS
	Girls	10.7 \pm 11.6		53.3 \pm 50.0	
13-14	Boys	45.1 \pm 40.5	0.001	134.3 \pm 102.8	0.005
	Girls	31.4 \pm 38.0		103.3 \pm 92.2	
18-19	Boys	81.5 \pm 104.6	0.001	200.5 \pm 167.3	0.001
	Girls	37.5 \pm 64.3		101.8 \pm 86.5	

*Carbonated soft drinks, juice, still fruit drinks and sport drinks

cisors (tooth numbers 21/11) and cupping scores for tooth numbers 36/46, the sensitivity and specificity for predicting severe/very severe dental erosion were 100% and 98%, respectively, compared to grading all buccal and palatal surfaces on anterior teeth and all first molars. The corresponding figures for the primary teeth (palatal surfaces of maxillary central incisors and all first primary molars) were 100% for both sensitivity and specificity.

Discussion

The age groups for this study were chosen in consideration of different social and dental developmental stages. The youngest group of 5-6 year-olds typically have mainly primary teeth and are still dependent on parental care while the 13-14 year-olds have permanent teeth, have reached a greater level of independence and freedom, and fostered new friends and possibly habits in secondary schools. The 18-19 year-olds are typically about to leave the organized dental care system and will soon leave home, representing a generation with established behaviour strongly influenced by societal factors, e.g. dietary, computer/television habits, etc. In Sweden, almost all individuals in these age groups across all the socioeconomic scales receive their dental care from the Public Dental Service. Therefore, the sample is probably representative for these age groups of the Swedish population living in medium and small sized communities which Nora and Storå represent.

The scale for grading the severity of dental erosion has been extensively used in similar studies and it has been shown that it was associated with cuppings (20). The intraexaminer concordance was acceptable for scoring of cuppings (~80%) for both permanent and primary teeth. It was lower for maxillary anterior teeth (71% and 64% for permanent and primary teeth, respectively). However, it was felt that the grading of the grades 3 and 4 erosion (Table 1) seemed reliable from a clinical standpoint although in the calibration data set the number of recorded grade 3 and 4 erosion was too small for meaningful statistical analysis to be performed. Primary teeth have generally less pronounced anatomical structures than permanent teeth and changes of the surface anatomy, which is the early stages of dental erosion, may therefore be more difficult to detect. In addition, small children may have more problems to cooperate during the clinical examination. Consequently, assessment of dental erosion in primary teeth is connected with some uncertainties. Intraexaminer concordance was also somewhat lo-

wer compared to permanent teeth which verify that they are more difficult to assess.

The lesions formed by dental erosion typically appear as eroded buccal/palatal surfaces on maxillary anterior teeth and as cuppings on molars (8, 12, 18, 21). The method of using marker teeth, partial recording, has previously been evaluated. Johansson et al. (17) found that maxillary anterior teeth were most reliable for assessing erosion and that the palatal surfaces were the most commonly affected. In addition, first molar cuppings were also associated to the presence of anterior tooth erosion (18). This finding was later confirmed in another study where partial recording (grading first molar occlusal surfaces and palatal surfaces of upper incisor and canine teeth) resulted in a very small loss of information compared to full mouth scoring (25). It has also been stated that cupped lesions on the mandibular first permanent molar indicates the age of onset and severity of dental erosion (21).

In this study, recordings of smooth surface erosion and cuppings were performed on 6 maxillary anterior canine and incisor teeth (buccal and palatal surfaces or 13/53 to 23/63) and 4 permanent first molars or 8 primary molars, giving a total of 16/20 surfaces. When using SEPRS, the sensitivity and specificity for detecting grade 3 and 4 erosion were 100% and 98%, respectively, in permanent teeth (4 surfaces). The corresponding figures for primary teeth (6 surfaces) were 100% for both sensitivity and specificity. The method used for the grading of erosion on these four or six marker surfaces is relatively easy to use and not too time consuming compared to other scoring systems.

Methods which involve complete recording of the dentition give more information, but the gain might be limited, especially in epidemiological research, considering that the increased time consumption allow most probably a substantial lesser numbers of individuals to be examined. In epidemiological research it is suggested that the SEPRS using 4 respectively 6 marker teeth and surfaces is implemented.

In the clinical setting during routine examination either of the partial recording systems used in this study could be applied. However, in patients where the partial recording system has detected erosive damages, additional recording should be considered. It has to be stated clearly, that full mouth recording of dental erosion in regular clinical practice is costly and may even be unethical due to the extended examination time that is imposed and that unnecessary information is retrieved without providing any additional benefit for the patient.

The prevalence of severe/very severe dental erosion for all three age groups was 16.4%, and was generally higher for boys than girls. The highest figure was found in 18-19 year-old boys, 34% of whom had one or more teeth affected by severe/very severe erosion. The present overall prevalence compares favourably with that found in studies from other countries, and represents generally a median value of other studies (for reviews see refs. 15 and 20). In the neighbouring Scandinavian country of Denmark, however, only about 2% of 15-17 year-old children exhibited erosion into dentine (22). However, it has to be borne in mind that it is very difficult to compare different studies due to wide variations in methodology in grading dental erosion. Nevertheless, it can be concluded that the prevalence of erosion in the present study was alarmingly high.

In US, a national survey found that 4-8, 9-13 and 14-18 year-olds consumed 377, 516 and 808 ml of soft drinks daily, (corresponding to 138, 188 and 295 L/year), respectively (4), while Icelandic teenage males consumed about 800 ml of carbonated drinks per day (292 L/year) (5). The consumption of soft drinks is regarded as one of the main causes to dental erosion in children and adolescents (20). In this study, all soft drink consumption increased with age and was highest among 18-19 year-old boys who consumed an average of 200 l/year. In all age groups besides 5-6 year-olds, boys consumed significantly more soft drinks than girls. The significant correlation found here between soft drink consumption and dental erosion has previously been reported and is, therefore, not surprising (3, 16-19, 26).

The hypothesis that dental erosion is higher in boys and that dental erosion is correlated with soft drink consumption was confirmed. In view of the high prevalence of dental erosion and soft drink consumption among Swedish adolescents reported here, especially among 18-19 year-old boys, there is a need to introduce nationwide epidemiological routines for recording dental erosion as well as community-based preventive programs from an early age.

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