

Prevalence of Erosive Tooth Wear and Associated Dietary Factors among a Group of Finnish Adolescents

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Keywords

Erosive tooth wear · Diet · Adolescent

Abstract

The aim of this study was to investigate the prevalence and severity of erosive tooth wear (ETW) among Finnish adolescents and to evaluate how frequency as well as amount of the use of erosive products is associated with ETW. The study population consisted of 328 voluntary, >15-year-old secondary school students (males 49.1%, females 50.9%) in three municipalities in Finland. Clinical examination to measure ETW (BEWE index) was carried out by trained and calibrated dentists. Piloted questionnaires included questions on consumption of drinks, fruits and berries, as well as tooth brushing frequency. Means and medians of frequencies and amounts of consumed erosive products were calculated and associations with ETW severity were analysed by logistic regression models. One-third (36.9%) of the participants were

in need of at least preventive measures for ETW (BEWE sum score ≥ 3), but severe ETW (BEWE sum score > 9) was rare (2.1%). Boys had severe ETW significantly more frequently than girls ($p < 0.001$). Habitual consumption of erosive drinks was common especially among boys compared to girls ($p = 0.001$). ETW was significantly associated with the amount of consumed erosive drinks, fruits, or berries. The prevalence of ETW among adolescences in Finland seems to be at the same level as in other Nordic and European countries. Consumption of erosive products is common and thus, the risk for tooth erosion is high, especially in boys. In addition to erosive drinks, also berries and fruits are associated with ETW and should be included in individual dietary counselling when early signs of ETW are clinically detected.

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Introduction

Erosive tooth wear (ETW) is an irreversible condition where dental hard tissue is lost due to chemical dissolution by acid from either extrinsic or intrinsic origin without any bacterial involvement [Lussi and Ganss, 2014]. According to recent studies, the prevalence of ETW seems to be increasing, especially among children and adolescents [Lussi and Jaeggi, 2008; Stenhagen et al., 2017; Marques Martinez et al., 2019]. A systematic review on children and adolescents suggested the average global prevalence rate of ETW to be 30.4% ranging from 7.2 to 74.0% [Salas et al., 2015]. Corresponding ETW prevalence rates on adolescents have been reported in other European and American studies [Arnadottir et al., 2010; Mulic et al., 2013; Søvik et al., 2015; Racki et al., 2020; Martignon et al., 2021]. However, currently Finland lacks such evidence-based data on the prevalence and the severity of ETW among adolescents.

Behavioural lifestyle factors such as drinking and eating habits are important etiological factors in the pathogenesis of ETW [Mulic et al., 2013; Lussi and Ganss, 2014]. A diet containing soft drinks and energy drinks and fruit juices appears to be the main extrinsic cause for ETW among children and adolescents [Dugmore and Rock, 2004; Hasselkvist et al., 2016; Skalsky Jarkander et al., 2018; Chan et al., 2020]. Worth noticing is that a healthy lifestyle diet containing lots of fruits and vegetables may also increase the risk for ETW [Johansson et al., 2012; Mulic et al., 2012; Isaksson et al., 2013].

Several studies have suggested that the prevalence of ETW is higher among males than among females [Mulic et al., 2012; Søvik et al., 2015; Struzycka et al., 2017]. However, opposite reports have been published as well [Bartlett et al., 2013; Vered et al., 2014; Provatenou et al., 2016].

The studies on ETW are challenging to compare since there is no universally accepted index for diagnosing ETW [Milosevic, 2011] and the diagnostic criteria for ETW vary between studies. However, there is a consensus that ETW is challenging to diagnose, especially in its early stages [Lussi and Ganss, 2014; Alaraudanjoki et al., 2017]. Numerous indices have been developed to evaluate and measure erosive tooth wear (ETW). The Basic Erosive Tooth Wear Examination (BEWE), one of these classifications, classifies the degree of hard tissue loss on the tooth surfaces [Bartlett et al., 2008; Aránguiz et al., 2020].

The aim of the study was to investigate the prevalence and severity of ETW among adolescents in Finland. Additionally, we aimed to evaluate how the frequency of use as well as the amount of erosive products associated with ETW.

Material and Methods

Study Population

Dental erosion among teenagers was studied in three municipalities: Sievi, Vaasa, and Kuopio. In Sievi and Vaasa, the studies were carried out during years 2018 and 2019 and in Kuopio between 2016 and 2019. Sievi and Vaasa are situated in the middle of Western Finland; the rural municipality of Sievi has approximately 5,000 and the City of Vaasa 65,000 inhabitants. The City of Kuopio, including both urban and rural areas, is located in Eastern Finland with 118,000 inhabitants.

All 15-year-old students in Sievi secondary school ($n = 77$) as well as in Vaasa Variska secondary school ($n = 150$) were invited to participate in the cross-sectional study. The principals of the two schools were contacted, and an electronic information letter was sent to the caregivers of all participants. All voluntary students who gave their informed written consent were included in the study (Sievi $n = 65$, Vaasa $n = 82$). Moreover, 182 adolescents (89 girls, 93 boys) aged 15–17 years who had undergone dental examinations in 2016–2019 as part of the 8-year follow-up phase of the Physical Activity and Nutrition in Children (PANIC) study [Methuen et al., 2021; Sallinen et al., 2022] were included in the current study. The recruitment of participants for the PANIC study has been described in detail earlier [Lakka et al., 2020]. In brief, 736 children aged 6–9 years who started the first grade in 16 primary schools of the city of Kuopio in 2007–2009 were invited to participate in the study. Altogether 512 (70%) children accepted the invitation and attended the baseline examinations in 2007–2009. The participants did not differ in gender distribution, age, or body mass index-standard deviation score at baseline from all children who started the first grade in the city of Kuopio in 2007–2009 [Lakka et al., 2020]. Neither did the adolescents attending the 8-year follow-up examinations differ in gender distribution or body mass index-standard deviation score from a reference population of adolescents of the same age in Finland [Methuen et al., 2021; Sallinen et al., 2022]. Data for the present analyses were obtained from 182 children, 49% girls and 51% boys. Mean (SD) age of the participants in Kuopio was 16.5 (0.5) years.

Clinical Examination

In all municipalities, ETW was measured by sextant using the BEWE index [Bartlett et al., 2008]. According to BEWE criteria, value 0 represents sound tooth surface, value 1 represents mild erosive loss of tooth substance, value 2 represents a case where less than 50% of the tooth surface has been lost, and value 3 represents a case where greater than 50% tooth surface has been lost. The dentists who performed the examinations were calibrated by senior researchers familiar with the ratings and training [Alaraudanjoki et al., 2016; Karki et al., 2021]. In all locations, training on the study protocol was organized and criteria reviewed using a PowerPoint presentation. In uncertain cases, a less severe BEWE score was chosen.

In Sievi and Vaasa, the dental examination was carried out on the school premises and in Kuopio in a dental office at the University of Eastern Finland. The examination was carried out by using a probe, oral mirror, and loop with a light. For moisture control in Sievi and Vaasa, cotton rolls were available as well as for removal of plaque when necessary. In Kuopio, a three-in-one syringe was used for drying tooth surfaces and removal of plaque was carried out by using cotton rolls or a probe. Each ETW examination took on average 5

min. All the examiners were trained by senior researcher (VA) to ensure similar understanding and diagnosing of ETW.

In Sievi and Vaasa, all participants were examined by two clinicians: ViA and M-LL in Sievi and ViA and HK in Vaasa, who together came to a consensus on all BEWE scores for each patient. Each BEWE value was evaluated together concurrently for each participant. In Kuopio, clinical examinations were carried out by an experienced clinician (MM).

Both in Sievi and Vaasa the examinations were carried out within two school days. Because in Kuopio the examinations were done over a long period of time, training and calibration were carried out at baseline and after that for quality assurance; calibration was repeated every 3 months by an experienced dentist (golden standard, VA). In these occasions, parallel investigations ($n = 13$) were conducted to evaluate inter-examiner agreement between the examiner and the senior researcher (golden standard). To investigate inter-examiner agreement in Kuopio, kappa values were calculated: mean $\kappa = 0.625$ (SD 0.305, min 0.278, max 1,000).

Questionnaire

In Sievi and Vaasa, the participants were interviewed by trained assistants (dental nurse/dental hygienist/dental student) before the dental examination. In the interview, a piloted questionnaire [Margaritis et al., 2020] was used. The questionnaire included gender of the participant as well as tooth brushing frequency (more than once a day/once a day or almost once a day/occasionally during the week/never or hardly ever). Additionally, frequency of consumption of (1) soft drinks, (2) energy or/and sport drinks, (3) fruit or/and berry juices, and (4) fruits or/and berries was asked (more than once a day/once a day or almost once a day/occasionally during the week/never or hardly ever) as well as amount (number of glasses/bottles/cans and number of fruits/handful of berries per day/week). One glass was considered as 2 dL and according to the size of the bottle/can its content was converted into decilitres. One handful of berries represented 1 dL.

In Kuopio, health-related behaviours were achieved from the PANIC database by using a questionnaire: Tooth brushing frequency was asked using the question “How often do you brush your teeth?” (more often than twice a day/twice a day/once a day/many times per week/once a week or more seldom/never). The questionnaire included questions concerning consumption of soft or energy drinks, fruit or berry juices, sugar-free soft drinks or juices, and fruit or berries. The frequency (every day/6 times a week/5 times a week/4 times a week/3 times a week/2 times a week/once a week/more seldom than once a week/never) and amount (number of glasses [2 dL] of drinks and number of fruits or decilitres of berries per day) were recorded.

Statistics

The study population was described as frequencies and proportions. BEWE index was presented per sextant and respective mean BEWE indices (SD) as well BEWE sum scores were calculated.

For the analyses, consumption of all erosive drinks was grouped to include soft and energy drinks, fruit and berry juices, and in Kuopio additionally sugar-free soft drinks and juices. Besides drinks, the variable all erosive products included consumption of fruits and berries. To combine the outcomes in different municipalities, the frequencies of consumption of drinks, fruits and berries were further categorized as daily/occasionally during the week/less than once a week.

Average daily amount of erosive drinks was presented in decilitres. Fruits were considered per piece and berries by decilitre. In the analyses, 1 dL of drinks or berries and one piece of fruit were considered as one portion. Amount of erosive drinks, fruits or berries, and erosive products were dichotomized using the median as a cut-off value in the entire study population and separately among boys and girls.

The χ^2 test was used to study the differences in distributions of frequencies and amounts of erosive drinks, fruits or berries, and erosive products by location and gender. Association of frequency and categorized amount of erosive drinks and products with occurrence of severe erosion (BEWE sum score $<$ and ≥ 3) were analysed by χ^2 tests and strength of associations with Cramer's V . When the cells had expected counts less than 5, we have used Fisher exact test. Normality of the distributions of amounts (dL) of erosive drinks, fruits and berries, and erosive products were checked by using plots and skewness (>1) and found not normally distributed. The differences were considered statistically significant with $p < 0.05$.

Logistic regression analyses were used to study associations of frequency and amount of consumption of erosive drinks and products with occurrence of a BEWE sum score ≥ 3 , ORs (95% CI) and Cohen's d -values were calculated using Practical Meta-Analysis Effect Size Calculator [https://www.campbellcollaboration.org/escal/html/Effect-Size-Calculator-OR-main.php, 2022]. Frequencies and amounts were included simultaneously in models to see their independent effects. Amounts were first used as original, continuous variables (Models I and III) and further as categorized by median (Models II and IV). Separate models were fitted for drinks (Models I and II) and products (Models III and IV) because drinks were included in all erosive products and due to this correlation between them was high (Pearson $r = 0.982$). All associations were adjusted for gender, location (Kuopio vs. Sievi/Vaasa), and tooth brushing frequency. For models including consumption of erosive products, statistics for goodness of fit (p values is below 0.05), indicated interactions or non-linearities in the models. To study interactions between gender and amount of erosive drinks and products, product terms of categorized amount of erosive drinks and gender were added in Models II and IV. Significant interactions were detected between gender and categorized amount of erosive drinks ($p = 0.032$) and categorized amount of erosive products ($p = 0.037$). Therefore, analyses were stratified by gender. All analyses were executed by using SPSS software (version 26.0, Chicago, IL, USA) and SAS 9.4. (SAS Institute Inc., Cary, NC, USA).

Ethical Considerations

Participation was voluntary, and no compensation was given to the participants. Data were collected and analysed without personal identification data. In Vaasa and Sievi, informed written consent was obtained from all participants. According to Finnish legislation, parents/caregivers of adolescents aged 15–18 years should be informed, but written consent from them is not required. Students' parents/caregivers were informed before the study. An ethical statement was given by the Ethical Board of Northern Finland Hospital District (PPSHP), approval number 70/2017, 240\$. In Kuopio, all participants and their parents/caregivers gave their informed written consent for participation. The study protocol was approved by the Research Ethics Committee of the Hospital District of Northern Savo (PSSHP), approval number November 10, 2015/295\$.

After clinical examination, all participants were given information on their dental health, particularly concerning tooth wear. If dental treatment was considered necessary, the participants were referred to primary dental health care.

Table 1. Gender, location, and the Basic Erosive Tooth Wear Examination (BEWE) scores of the participants

	Sievi (<i>n</i> = 65)	Vaasa (<i>n</i> = 81) ^a	Kuopio (<i>n</i> = 182)
Gender			
Boys	35 (53.8)	33 (40.7)	93 (51.1)
Girls	30 (46.2)	48 (59.3)	89 (48.9)
Location	65 (100)	81 (100)	182 (100)
BEWE sum score			
0	12 (18.5)	10 (12.3)	86 (47.3)
1–2	30 (46.2)	11 (13.6)	58 (31.9)
3–8	20 (30.8)	59 (72.8)	35 (19.2)
9–13	3 (4.6)	1 (1.2)	3 (1.7)
14+	–	–	–
BEWE 1. sextant (dd 17–14)			
0	41 (63.1)	38 (46.9)	147 (80.8)
1	22 (33.8)	43 (53.1)	32 (17.6)
2	2 (3.1)	0 (0.0)	3 (1.7)
3	–	–	–
BEWE 2. sextant (dd 13–23)			
0	51 (78.5)	44 (54.3)	165 (90.7)
1	12 (18.5)	36 (44.4)	15 (8.2)
2	2 (3.1)	1 (1.2)	2 (1.1)
3	–	–	–
BEWE 3. sextant (dd 24–27)			
0	40 (61.5)	42 (51.9)	151 (83.0)
1	21 (32.3)	39 (48.1)	29 (16.0)
2	4 (6.2)	0 (0.0)	2 (1.1)
3	–	–	–
BEWE 4. sextant (dd 37–34)			
0	31 (47.7)	21 (25.9)	98 (53.9)
1	26 (40.0)	52 (64.2)	78 (42.9)
2	7 (10.8)	7 (8.6)	5 (2.8)
3	1 (1.5)	1 (1.2)	1 (0.6)
BEWE 5. sextant (dd 33–43)			
0	62 (95.4)	48 (59.3)	168 (92.3)
1	3 (4.6)	29 (35.8)	14 (7.7)
2	0 (0.0)	4 (4.9)	–
3	–	–	–
BEWE 6. sextant (dd 44–47)			
0	28 (43.1)	24 (29.6)	103 (56.6)
1	29 (44.6)	49 (60.5)	75 (41.2)
2	7 (10.8)	7 (8.6)	3 (1.7)
3	1 (1.5)	1 (1.2)	1 (0.6)

Values are *n* (%). ^aOne participant in Vaasa did not participate in clinical examination.

Results

The study group consisted of altogether 328 secondary school students from Kuopio (*n* = 182), Vaasa (*n* = 81) and Sievi (*n* = 65). Of them, 161 were males (49.1%) and 167 females (50.9%). Almost two-thirds of the participants had BEWE sum scores <3 (*n* = 207, 63.2%), one-third had BEWE sum score 3–8 (*n* = 114, 34.8%), a few BEWE sum score 9–13 (*n* = 7, 2.1%), and none had BEWE sum score above 13 (*n* = 0, 0.0%). One-third (36.9%) of the participants needed at least preventive measures for ETW (BEWE sum score ≥3). Severe ETW (BEWE sum score >9) was rare (2.1%). Boys (48.5%) had ETW (BEWE sum score ≥3) significantly more frequently than girls (25.8%), with similar results in all three locations (*p* < 0.001): in Kuopio, 33.3 versus 7.9%, *p* < 0.001; in Sievi, 51.4 versus 16.7%, *p* = 0.004; in Vaasa, 87.8 versus 64.6%, *p* = 0.019. The distribution of BEWE scores by sextants is presented in Table 1. Anterior sextants were least affected, whereas on average 50% of the participants had at least mildly affected lower molars (BEWE sum score >2).

The consumption of erosive drinks at least sometimes during the week was common. Boys consumed erosive drinks significantly more frequently than girls (*p* = 0.001); however, the difference between genders was lowest in Vaasa. Almost all boys and girls ate fruit or berries or consumed erosive drinks at least sometimes during the week. Tooth brushing frequency was statistically significantly higher among girls than boys (online suppl. Table. S1; see www.karger.com/doi/10.1159/000527305 for all online suppl. material).

The median value of consumed erosive drinks was 4.7 dL/day and of erosive products 6 portions/day in the whole study group. Associations between ETW (BEWE sum score <3 or ≥3) and the frequencies of the use of erosive products were not statistically significant (Table 2). Amounts of the use of fruits and berries in Vaasa (*p* = 0.005 with moderate effect size 0.317) and erosive products in Kuopio (*p* = 0.046 with small effect size 0.148) were significantly associated with ETW. According to logistic regression analyses, both amounts of erosive drinks (as continuous, dL/day, OR 1.1, 95% CI: 1.0–1.2) and erosive products (as continuous, portions/day, OR 1.1, 95% CI: 1.0–1.2) associated significantly with a BEWE sum score ≥3. In addition, boys had more than three times higher odds than girls for having a BEWE sum score ≥3 (Table 3). In stratified analyses according to gender, the amount of erosive products (as continuous, portions/day, OR 3.0, 95% CI: 1.1–8.4) associated significantly with a BEWE sum score ≥3 among boys but not among girls (Table 4).

Table 2. Consumption of erosive drinks and products by location and the categorized Basic Erosive Tooth Wear Examination (BEWE) index

	Sievi			Vaasa			Kuopio		
	BEWE 0–2 (n = 42)	BEWE ≥3 (n = 23)		BEWE 0–2 (n = 21)	BEWE ≥3 (n = 60)		BEWE 0–2 (n = 144)	BEWE ≥3 (n = 38)	
<i>Erosive drinks</i>									
Frequency, n (%)									
Daily	10 (52.6)	9 (47.4)	0.388 ¹	5 (26.3)	14 (73.7)	0.766 ¹	13 (81.3)	3 (18.8)	0.286 ¹
Sometimes during the week	23 (67.7)	11 (32.4)	0.171 ²	14 (25.0)	42 (75.0)	0.082 ²	105 (76.6)	32 (23.4)	0.117 ²
More seldom	9 (75.0)	3 (25.0)		2 (40.0)	3 (60.0)		26 (89.7)	3 (10.3)	
Missing					1				
Amount, dL/day									
≤Median	13 (68.4)	19 (63.0)	0.680 ¹	13 (28.3)	33 (71.7)	0.583 ¹	79 (84.0)	15 (16.0)	0.084 ¹
>Median	6 (31.6)	17 (37.0)	0.051 ²	8 (22.9)	27 (77.1)	0.061 ²	64 (73.6)	23 (26.4)	0.129 ²
Missing							1		
<i>Fruits or berries</i>									
Frequency, n (%)									
Daily	23 (63.9)	13 (36.1)	0.187 ¹	9 (20.0)	35 (80.0)	0.407 ¹	38 (86.4)	6 (13.6)	0.297 ¹
Sometimes during the week	18 (72.0)	7 (28.0)	0.227 ²	10 (34.5)	19 (65.5)	0.150 ²	99 (76.2)	31 (23.9)	0.116 ²
More seldom	1 (25.0)	3 (75.0)		2 (28.6)	5 (71.4)		7 (87.5)	1 (12.5)	
Missing					1				
Amount, dL/day									
≤Median	28 (65.1)	15 (34.9)	0.780 ¹	15 (41.7)	21 (58.3)	0.005 ¹	67 (73.6)	24 (26.4)	0.068 ¹
>Median	13 (68.4)	6 (31.6)	0.032 ²	6 (13.6)	38 (86.4)	0.317 ²	77 (84.6)	14 (15.4)	0.135 ²
Missing	1				1				
<i>Erosive products</i>									
Frequency, n (%)									
Daily	29 (61.7)	18 (38.3)	0.427 ¹	11 (21.1)	41 (78.9)	0.161 ¹	48 (84.2)	9 (15.8)	0.316 ¹
Sometimes during the week	13 (72.2)	5 (27.8)	0.099 ²	8 (32.0)	17 (68.0)	0.214 ²	93 (76.2)	29 (23.8)	0.113 ²
More seldom	0	0		2 (66.7)	1 (33.3)		3 (100)	0	
Missing					1				
Amount, dL/day									
≤Median	21 (70.0)	9 (30.0)	0.533 ¹	12 (29.3)	29 (70.7)	0.529 ¹	86 (84.3)	16 (15.7)	0.046 ¹
>Median	20 (62.5)	12 (37.5)	0.079 ²	9 (23.1)	30 (76.9)	0.070 ²	57 (72.2)	22 (27.9)	0.148 ²
Missing	1	2			1		1		

¹ *p* for χ^2 test or Fisher exact test when 50% of the cells have expected counts less than 5. ² Cramer's V, *df* = 1.

Discussion

Our study revealed that ETW and consumption of erosive products (drinks, fruits, or berries) are common among Finnish teenagers. One-third of the participants needed at least preventive measures to address ETW, but severe erosive wear was rare. The results found in this study indicate that prevalence of ETW in Finland is in line with other Nordic and European countries. The prevalence of ETW was higher among boys than girls which was also previously reported in several studies [Dugmore and Rock, 2004; Mulic et al., 2013; Hasselkvist et al., 2016;

Skalsky Jarkander et al., 2018]. In addition to higher consumption of erosive drinks, higher bite strength could be one explanation for males being more susceptible for developing ETW than females [Bardsley et al., 2004; Smith et al., 2006]. It has also been indicated that enamel in males seems to be more prone to ETW than in females according to the genetic variation in enamel formation genes [Uhlen et al., 2016].

High consumption of soft drinks is suggested to be the main external factor for ETW among teenagers [Salas et al., 2015; Skalsky Jarkander et al., 2018; Chan et al., 2020]. In line with other studies [Visram et al., 2016; Melbye et al.,

Table 3. Adjusted associations of consumption of erosive drinks or erosive products with occurrence of erosive tooth wear (BEWE sum score ≥ 3) by logistic regression

	Model I		Model II ¹		Model III		Model IV ²	
	OR (95% CI)	Cohen's <i>d</i>	OR (95% CI)	Cohen's <i>d</i>	OR (95% CI)	Cohen's <i>d</i>	OR (95% CI)	Cohen's <i>d</i>
Boys (ref. girls)	3.2 (1.8–5.8)	0.64	3.5 (2.0–6.3)	0.69	3.4 (1.9–6.1)	0.68	3.6 (2.0–6.4)	0.71
Sievi and Vaasa (ref. City of Kuopio)	10.7 (4.9–23.5)	1.31	7.9 (3.6–17.1)	1.14	12.2 (5.3–27.8)	1.38	11.1 (4.6–26.6)	1.33
Tooth brushing frequency (ref. >once a day)								
Once a day	0.8 (0.4–1.5)	0.12	0.8 (0.4–1.6)	0.12	0.8 (0.4–1.8)	0.12	0.8 (0.4–1.4)	0.12
Sometimes during the week	1.0 (0.3–3.2)	0	1.1 (0.3–3.5)	0.05	0.9 (0.3–3.0)	0.06	1.0 (0.3–3.2)	0
Consumption of erosive drinks, frequency (ref. more seldom)								
Sometimes during the week	1.7 (0.7–4.2)	0.29	2.0 (0.8–4.7)	0.38				
Daily	1.1 (0.4–3.2)	0.05	1.4 (0.5–4.2)	0.19				
Consumption of erosive drinks, amount, dL/day								
	1.1 (1.0–1.2)	0.05						
Consumption of erosive drinks, amount (ref. \leq median, 4.7 dL/day)								
>4.7 dL/day			1.4 (0.7–3.0)	0.19				
Consumption of erosive products, frequency (ref. more seldom)								
Sometimes during the week					1.9 (0.2–19.3)	0.35	2.0 (0.2–20.3)	0.38
Daily					1.4 (0.1–13.8)	0.19	1.6 (0.2–15.9)	0.26
Consumption of erosive products, amount (portions/day)								
					1.1 (1.0–1.2)	0.05		
Consumption of erosive products, amount (ref. \leq median, 6 portions/day)								
>6 portions/day							2.0 (0.9–4.6)	0.38
Goodness of fit (Hosmer-Lemeshow)	$\chi^2 = 14.0$, <i>df</i> = 8, <i>p</i> = 0.083		$\chi^2 = 7.16$, <i>df</i> = 7, <i>p</i> = 0.413		$\chi^2 = 15.6$, <i>df</i> = 8, <i>p</i> = 0.048		$\chi^2 = 17.4$, <i>df</i> = 8, <i>p</i> = 0.026	

¹ Significant interaction (*p* = 0.032) between gender and categorized amount of erosive drinks (≤ 4.7 vs. > 4.7 dL/day). ² Significant interaction (*p* = 0.037) between gender and categorized amount of erosive products (≤ 6 vs. > 6 portions/day).

Table 4. Adjusted associations of consumption of erosive drinks or erosive products with occurrence of erosive tooth wear (BEWE sum score ≥ 3) in boys and girls by logistic regression

	Boys		Girls		Cohen's <i>d</i>	Cohen's <i>d</i>	Cohen's <i>d</i>		
	Model I		Model III					Model IV	
	OR (95% CI)	Cohen's <i>d</i>	OR (95% CI)	Cohen's <i>d</i>				OR (95% CI)	Cohen's <i>d</i>
Sievi and Vaasa (ref. City of Kuopio)	8.4 (3.2–22.1)	1.17	8.9 (3.1–25.4)	1.21	7.4 (1.8–30.5)	1.10	6.4 (1.7–24.6)	1.02	
Tooth brushing frequency (ref. > once a day)					n.a.		n.a.		
Once a day	0.8 (0.4–1.8)	0.12	0.7 (0.3–1.6)	0.20					
Sometimes during the week	1.2 (0.3–4.5)	0.10	1.3 (0.3–4.5)	0.15					
Consumption of erosive drinks (ref. more seldom)									
Sometimes during the week	1.4 (0.3–7.8)	0.19			1.8 (0.3–7.3)	0.32			
Daily	2.3 (0.5–9.9)	0.46			1.4 (0.3–7.3)	0.19			
Consumption of erosive drinks, dL/day	1.1 (1.0–1.2)	0.05			0.9 (0.8–1.2)	0.06			
Consumption of erosive products (ref. more seldom)									
Sometimes during the week			n.a.						
Daily									
Consumption of erosive products (portions/day)			3.0 (1.1–8.4)	0.61					
Goodness of fit (Hosmer-Lemeshow)	$\chi^2 = 11.40$, df = 8, $p = 0.180$		$\chi^2 = 2.54$, df = 7, $p = 0.924$		$\chi^2 = 5.24$, df = 8, $p = 0.732$		$\chi^2 = 2.84$, df = 8, $p = 0.944$		
n.a. non-applicable due to small number of observations. Cohen <i>d</i> calculated using Practical Meta-Analysis Effect Size Calculator.									

2020], consumption of erosive drinks was significantly more common in boys than girls. Additionally, the use of fruits or berries was as common in both genders. In most epidemiological studies, the focus has been on the association of ETW with frequency of acid intake, with less consideration given to the average intake amount. In this study, amounts of erosive products seemed to associate with the severity of ETW, especially in boys. As regards frequencies of the use of erosive products no clear association was seen, this was true among both genders. Søvik et al. [2015] found a dose-response relationship between the daily consumption of acidic drinks and dental erosive wear among Norwegian 16–18-year-old adolescents. Acidic beverage consumption was categorized into low (0–0.24 L/day), moderate (0.25–0.74 L/day), and high (0.75–5 L/day) consumption. Jensdottir et al. [2004] observed in Icelandic young adults a significant relationship with ETW when more than 1 L of carbonated drinks was consumed per day. Here, a median consumption of erosive drinks of 0.47 L/day was discovered in the whole study group. In the bivariate analyses, Cramer's V values showed some small (erosive products) to moderate (fruits) effect sizes and in the regression analyses Cohen d values showed only small effect sizes. However, in stratified analyses among boys, effect size (OR 3.0 and Cohen d 0.61) for consumption of erosive products represented medium or large effect. Today, sweets and soft drinks are often sold in large packages, which are often more economical to buy than small ones. According to our findings, already increase of 1 dL per day of erosive products increased the risk of ETW by 10%. Further studies on this topic are needed because evidence for an association between amount of acidic products and ETW remains somewhat unclear.

Fruits and berries are known to be good for one's health [Wallace et al., 2020]. However, it must be remembered that several fruits and berries contain erosive acids. Here, indeed, high amounts of fruits and berries were associated with ETW. Interestingly, Gillborg et al. [2020] found, that also among Swedish adults, daily consumption of fruits had a stronger correlation to ETW than acidic drinks. Citrus fruits are considered to be at the highest end of the acid spectrum [Järvinen et al., 1991]. Yet, in their systematic review, Chan et al. [2020] concluded that citrus fruits, like lemons, oranges, and grapefruits were only marginally more likely to be associated with dental erosion compared to other types of fruits.

Tooth brushing frequency was statistically significantly higher among girls than boys, but it was not associated with ETW. This finding, supporting that brushing frequency is not associated with ETW, is in line with the

previous studies [Søvik et al., 2015; Marques Martinez et al., 2019].

The BEWE [Bartlett et al., 2008] rating was used in this study to describe the hard tissue loss on tooth surfaces in all three municipalities. Diagnostic criteria for ETW vary between studies and ETW is challenging to diagnose, especially in its early stages. This challenge existed also in this study and may be the reason for non-excellent inter-examiner agreement in Kuopio. In all locations, all the clinical examiners were trained and calibrated for diagnosing ETW and using BEWE index by the same experienced expert in the field. Basis for diagnose of ETW was similar in all municipalities but in Kuopio examination period lasted for 2 years whereas in Vaasa and Sievi only for 2 days each. The differences in the prevalence of ETW between the municipalities may be partly explained by the differences in the way of diagnosing ETW. Variety of the data was standardized by regression analyses which controls their effects on the outcome. The data of Kuopio and Vaasa-Sievi could be merged but some risk of bias may exist in combined data [Mickenautsch and Yengopal, 2011].

Comprehensive data on ETW-related behavioural and dietary factors were available from all locations and gave an opportunity to investigate both the frequency and quantity of products and drinks consumed, in relation to the severity of ETW. A piloted questionnaire according to the health-related behaviours was used in Sievi and Vaasa [Margaritis et al., 2020]. Similar kinds of responses were archived from the Kuopio PANIC database [<https://uefconnect.uef.fi/en/group/the-physical-activity-and-nutrition-in-children-panic-study/>, 2022]. Thus, the responses to questionnaires were comparable and it was possible to analyse the data.

The study population in this clinical study is more than 300. Even though this study does not represent all Finnish adolescents, in the results we are able to see ETW tendency among adolescents in Finland. According to the regular Finnish School Health Promotion studies [Finnish Institute of Health and Welfare], there are no remarkable differences in health-related habits among adolescents in different parts of Finland. Thus, this study sample can be considered as representative in relation to the overall adolescent population living in Finland. There is no previous data available on the prevalence of ETW among Finnish adolescents. Therefore, this study gives valuable scientific evidence on the topic in Finland. The results can be applicable at least to populations of similar characteristics also in other countries. Our findings should, however, be confirmed with larger study populations and follow-up studies.

In all these municipalities, oral health promotion including preventive counselling is conducted as needed individually at dental offices as well as in school-based tutorial groups according to the regular/national protocol [Ministry of Social Affairs and Health, 2006; Quality Recommendation for Health Promotion]. However, in Kuopio PANIC intervention focuses on dietary counselling, which some participants had received for 8 years. Early diagnosis of ETW enables dental professionals to conduct preventive measures in the office as well as, e.g., to give information for modifying eating and drinking habits. This works towards avoiding the worst-case scenario of expensive and complicated restorative treatments to replace lost tooth substances in the future [Carvalho et al., 2015]. While Finnish dental professionals seem to be increasingly aware of ETW, it is unfortunate that the use of the ETW scoring system seems to be only occasional [Kangasmaa et al., 2021].

The limitation of cross-sectional study setting is that it does not allow to draw conclusions on causality, here between ETW and erosive products, even though associations are observed. By combining two datasets, the power of the study could be increased, but however, combined data can also be considered as a limitation. Additionally, these data do not permit further analyses considering socio-demographics or socio-economic status in association with ETW. Questionnaires are widely used in epidemiological studies, but there can be some inaccuracy how precisely participants remember past dietary habits and how truly and decently they want to respond [Shim et al., 2014]. In a survey like this, there might be a tendency to provide favourable responses in questionnaires and interviews, but it can be assumed that among teenagers this source of bias may not be as common as among adults [Sjöström and Holst, 2002]. However, this was the first study in Finland investigating ETW among adolescents in general population. The results indicate that early signs of ETW are common already among 15-year-olds and therefore, importance of preventive measures and all efforts to control ETW are emphasized.

Conclusion

Erosive tooth wear, as well as consumption of erosive products, is common among Finnish adolescents and the risk for tooth erosion is high, especially in boys. Our findings suggest that besides frequency, there is an association between the amount of erosive products and ETW but further studies are needed.

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Statement of Ethics

Participation was voluntary, and no compensation was given to the participants. No personal data were gathered, and anonymity of the participants was ensured. In Vaasa and Sievi, informed written consent was obtained from all participants. According to Finnish legislation, parents/caregivers of adolescents aged 15–18 years should be informed, but written consent from them is not required. Students' parents/caregivers were informed before the study. An ethical statement was given by the Ethical Board of Northern Finland Hospital District (PPSHP), approval number 70/2017, 240\$. In Kuopio, all participants and their parents/caregivers gave their informed written consent for participation. The study protocol was approved by the Research Ethics Committee of the Hospital District of Northern Savo (PSSHP), approval number 10.11.2015/295\$.

Conflict of Interest Statement

The authors declare that they have no competing interests.

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Author Contributions

Mirja Methuen, Hanna Kangasmaa, Viivi Alaraudanjoki, Vuokko Anttonen, Anna Liisa Suominen, and Marja-Liisa Laitala designed the study. Anna Liisa Suominen and Hannu Vähänikkilä analysed the data. Mirja Methuen, Hanna Kangasmaa, Viivi Alaraudanjoki, Vuokko Anttonen, Anna Liisa Suominen, Timo Lakka, and Marja-Liisa Laitala drafted the manuscript. Panu Karjalainen and Juuso Väistö prepared the data for analysis.

All the authors read and approved the final manuscript.

Data Availability Statement

Data can be requested from the authors. Permissions for data use must be granted by Kuopio and Oulu university authorities. Further enquiries can be directed to the corresponding author.

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