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Abstract

Background/Aim: Experimental studies have identified differences in the effect of physicochemical properties of beverages on the etiology of erosive tooth wear (ETW). Little is

known from epidemiological studies about the relationship between ETW and consumption of juices, drinks and milk. This study examined the relationship between the consumption of juices, drinks, milk and ETW in children in the United States. *Methods:* The National Health and Nutrition Examinations Survey data for 2003–2004 was analyzed. Trained and calibrated examiners used the modified Smith and Knight Tooth Wear Index from a 1998 United Kingdom Adult Health Survey to measure ETW. Beverage consumption collected via a Food Frequency Questionnaire was processed with Diet*Calc software to obtain the average daily consumption frequency for all queried juice categories, milk and carbonated beverages. Survey-weighted descriptive and multivariable analyses were performed. *Results:* Prevalence of ETW was highest in children aged 18–19 years (56%), males (49%), and lowest in Blacks (31%). Milk and soft drinks (0.85 times a day) and fruit drinks (0.69) were the most consumed products by children. Children with ETW had significantly higher odds of being frequent consumers of apple juice after adjusting for age, gender, and race/ethnicity. Blacks had the highest mean daily apple juice consumption, but the mean difference between those with ETW and those without ETW was not significant. *Conclusion:* ETW was associated with frequent intake of apple juice, but the mean difference in consumption between groups with ETW versus those without ETW within racial/ethnic groups was not significant.

Keywords

Carbonated beverages, Children. Erosive tooth wear, Juices, Milk, Race/ethnicity, Soft drinks, Youth

Introduction

Erosive tooth wear (ETW) is an irreversible condition that manifests as substantial loss of dental hard tissue due to chemical dissolution by acid from extrinsic and intrinsic sources without bacterial involvement. The pathophysiology associated with the loss of tooth structure in dental caries and ETW is different, but the damage to dental hard tissues is similar and both conditions require complex and expensive restorative care. If left untreated, ETW can lead to sensitive teeth, tooth discoloration, altered tooth shape, and has the potential to impact a child's dentition and oral health-related quality of life.

Few studies have investigated the association between ETW and dietary products in the United Kingdom and Saudi Arabia [Millward et al., 1994; Hinds et al., 1995; Johansson et al., 1997; Milosevic et al., 1997; Kelly et al., 1998; Dugmore and Rock, 2004] including one study conducted in the United States that used a convenience sample [Mungia et al., 2009]. Hartles and Wagg [1962] reported on the erosive potential of citric acid, fruit juices and other acids contained in some beverages on tooth enamel and dentin. Borrud et al. [1997] and Popkin [2010] reported an increase in the consumption of soft drinks and juices among children and adults in the United States. Nielsen and Popkin [2004] reported a threefold increase in the consumption of sweetened soft drinks and fruit drinks among children in North America between 1977 and 2001.

Studies have documented an increase in the prevalence of ETW [Milosevic et al., 2004; Árnadóttir et al., 2010] and its association with different extrinsic factors among children in

Europe [Nunn, 1996; Bartlett et al., 1998; Al-Dlaigan et al., 2001]. In addition, studies have also reported on the role of other extrinsic factors in the etiology of ETW, but these data have largely come from in vitro studies [Meurman et al., 1987, 1990; Rytömaa et al., 1988; Lussi et al., 1993, 1995, 1997, 2000, 2004; Hun- ter et al., 2008; Leslie et al., 2008; Murrell et al., 2010], case reports [Levine, 1973; Smith and Shaw, 1987; Millward et al., 1994; Cheng et al., 2009], and case controls [Järvinen et al., 1991; Milosevic et al., 1997].

An earlier study by our group using the National Health and Nutrition Examination Survey (NHANES) data reported that approximately 46% of American children aged 13–19 years had evidence of ETW in at least one tooth [McGuire et al., 2009]. However, this study did not examine the relationship between ETW and the consumption of acidic beverages. To the best of our knowledge, no epidemiological study using a nationally representative sample from the United States has examined the association between ETW and the consumption of beverages, adjusting for other potential risk factors. The aim of this study was to examine the association between ETW and the consumption of soft drinks, fruit juices, milk, and tomato/vegetable juices in children adjusting for potential covariates.

Methods

Data Source

We conducted a secondary data analysis using NHANES data for 2003–2004. NHANES 2003–2004 data included for the first time data on ETW which had never been collected in prior national surveys. The survey design used a stratified, multistage probability sample of counties, blocks, and individuals randomly selected from households. The sample was designed to be self-weighting within a primary sampling unit for age, sex, and race/ethnicity. Measurement of ETW in the NHANES survey followed a protocol that was developed by a partnership between the United States and international oral health experts and epidemiologists from the United Kingdom and Ireland. The article published by Dye et al. [2008] provides an overview and quality assurance for all the oral health components of the NHANES 2003–2004, including information on training and calibration of examiners for ETW [Dye et al., 2008].

Study Variables

The modified Tooth Wear Index of Smith and Knight [1984] was used to collect data on ETW in NHANES to allow for comparisons to be made with published reports from other countries [Dye et al., 2008]. The modified Tooth Wear Scores (TWS) were based upon the extent of enamel loss and dentin exposure for each eligible surface examined [Dye et al., 2008]. ETW was evaluated and scored visually by trained examiners for the lingual, facial, and incisal surfaces of maxillary central and lateral incisors and canines, mandibular central and lateral incisors and canines, and occlusal surfaces of the maxillary and mandibular first molars [Dye et al., 2008].

Summary statistics were conducted and no child had a TWS of 3, but a small number of children had a TWS of 2. As a result, TWS of 1 and 2 were combined into one variable to represent the group with ETW. Person-level ETW was quantified as the presence of marked wear on any surface in the enamel or dentin of examined teeth. Beverage consumption data was collected through a food frequency questionnaire and processed by NHANES using the Diet*Calc

software to obtain daily frequencies. This resulted in intake frequency values from 0 (never) to 7 (6 or more times a day) for milk (as a beverage), tomato/vegetable juice, orange/grapefruit juice, apple juice, grape juice, other fruit juice, fruit drinks (such as Hi-C and lemonade), soda in the summer, and soda during the rest of the year. The seasonal soda measurement was combined using a weighted average (1/4 weight for summer) to reflect average annual consumption. Race and ethnicity were combined by considering racial subdivisions (White, Black, other) among non-Hispanic respondents only. The study was approved by the Marquette University Institutional Review Board (No. HR-1518).

Tooth Wear Scoring System [Dye et al., 2008]

0 = Sound natural tooth surface. Any wear is restricted to the enamel and does not extend into dentin (all surfaces).

1 = Loss of enamel just exposing dentin (all surfaces).

2 = Loss of enamel exposing dentin for more than an estimated one third of the individual surface area (buccal, lingual surfaces). Loss of enamel and extensive loss of dentin, but not exposing secondary dentin or pulp. On occlusal/incisal surfaces exposed dentin facets with a buccal-lingual dimension of 2 mm or greater at the widest point will be seen (incisal and occlusal surfaces).

3 = Complete loss of enamel on a surface, pulp exposure, or exposure of secondary dentin where the pulp used to be. Frank pulp exposure is most unlikely (buccal, lingual surfaces). Pulp exposure or exposure of secondary dentin (incisal, occlusal surfaces).

Statistical Analysis

The general analysis approach followed the NHANES analytical guidelines in adjusting for the survey design. A two-sided 5% significance level was used throughout. The analysis was performed using SAS 9.2 (SAS Institute, Cary, N.C., USA), PROCs SURVEYFREQ, SURVEYLOGISTIC, and SURVEYREG as appropriate.

Results

The sample consisted of 1,314 children and 523 had evidence of ETW, completed the food frequency questionnaire and received a dental examination. The sample was weighted to represent children aged 13–19 years living in the United States. Based on the overall sample weighted information for children with ETW-age distribution was uniform, 45% had some evidence of ETW and 53% were female (data not shown). Table 1 shows the prevalence of ETW by demographic variables; the percent of children with ETW was highest in Whites (48.4%) and in children aged 18–19 years (55.5%) and also higher among males (48.9%). Detailed information on the characterization of the studied population with ETW from the NHANES database is available in the article published by McGuire et al. [2009]. This article reported that a higher rate of ETW was found on incisal surfaces of central incisors, canines, and on occlusal surfaces of molar teeth [McGuire et al., 2009].

Table 1

Weighted distribution of study population with ETW (n = 523)

Characteristics	Weighted percent with ETW (SE)	p value
Age, years		0.01
13–15	39.6 (6)	
16–17	44.5 (8.4)	
18–19	55.5 (7.5)	
Gender		0.30
Female	42.4 (7.5)	
Male	48.9 (6.8)	
Race/ethnicity		0.04
Hispanic	43.8 (8.1)	
Non-Hispanic White	48.4 (7.1)	
Non-Hispanic Black	30.6 (8.5)	
Other	43.1 (7.6)	

p value: refers to a test of equality of the rates of ETW between subgroups.

Table 2 shows the bivariate relationship between the consumption of different beverages and ETW. There were no significant differences in the frequency of consumption of the different beverages between children with ETW and those without ETW, but children with ETW had a higher observed frequency of consuming apple juice, orange/grapefruit juice and soft drinks than the overall mean rate of consumption. Among subjects with ETW, mean frequency consumption was highest for milk (0.85 times a day), soft drinks (0.85 times a day), and fruit drinks (0.69 times a day).

Table 2

Weighted daily frequency of juice/milk consumption by erosion status

Drink	Overall mean (SE)	Mean daily consumption of juices/milk		p value
		among subjects without ETW (SE)	among subjects with ETW (SE)	
Apple juice	0.34 (0.03)	0.32 (0.03)	0.36 (0.05)	0.42
Fruit drinks	0.69 (0.06)	0.71 (0.05)	0.69 (0.12)	0.91
Grape juice	0.13 (0.01)	0.14 (0.02)	0.12 (0.01)	0.35
Milk	0.86 (0.09)	0.86 (0.12)	0.85 (0.08)	0.91
Orange/grapefruit juice	0.57 (0.03)	0.53 (0.04)	0.62 (0.06)	0.32
Other juice	0.31 (0.03)	0.32 (0.04)	0.29 (0.05)	0.67
Soft drinks	0.81 (0.05)	0.76 (0.06)	0.85 (0.06)	0.24
Tomato/vegetable juice	0.08 (0.02)	0.08 (0.02)	0.07 (0.02)	0.65

Table 3 shows the result of a weighted multivariable logistic regression for factors associated with frequent consumption of different beverages. After adjusting for age, gender, and race/ethnicity, more frequent apple juice consumption was found to be associated with a higher likelihood of ETW (OR = 1.24, 95% CI 1.08–1.43, p = 0.003). No association was found for grape, orange/grapefruit, tomato/vegetable juice, juice drinks, soda, or milk. It is interesting to note that the above finding of a positive association between apple juice consumption and ETW

at the individual level seems to be reversed in grouped analyses. For example, while Blacks had the highest daily mean consumption of apple juice among all racial/ethnic groups (p = 0.006 vs. Whites, table 4), they had the lowest rates of erosion (table 2). Similarly, 18- to 19-year-olds had the highest rate of erosion among all age groups despite the fact that they consumed less apple juice than younger children (although this difference did not reach statistical significance). Within each racial/ethnic group or age range, children with ETW tended to consume apple juice more frequently, which was expected based on the individual level association, although statistical significance was not reached in these comparisons.

Table 3

Multivariable analyses of factors associated with ETW

Predictor/factor	Adjusted odds ratio (95% CI)
Apple juice	1.24 (1.08, 1.43)
Fruit drinks	1.03 (0.89, 1.19)
Grape juice	0.73 (0.50, 1.06)
Orange/grapefruit juice	1.10 (0.89, 1.37)
Tomato/vegetable juice	0.76 (0.42, 1.40)
Other juice	0.92 (0.75, 1.14)
Milk	0.95 (0.82, 1.10)
Soft drinks	1.15 (0.98, 1.36)

Adjusted for age, race, gender, and their interactions.

Table 4

Survey weighted linear regression of daily frequency of apple juice consumption by race, age and ETW

Characteristics	Mean apple juice consumption (SE)	p value	Mean among subjects without ETW (SE)	Mean among subjects with ETW (SE)	With ETW vs. without ETW difference (SE)	p value (with vs. without)
Race/ethnicity						
Non-Hispanic Black	0.81 (0.17)	0.0057	0.64 (0.17)	1.18 (0.35)	0.54 (0.39)	0.1823
Hispanic	0.47 (0.04)	<0.0001	0.45 (0.05)	0.49 (0.06)	0.04 (0.08)	0.6370
Other	0.14 (0.03)	0.1027	0.16 (0.04)	0.09 (0.04)	−0.06 (0.05)	0.2399
Non-Hispanic White	0.22 (0.03)	referent	0.20 (0.03)	0.23 (0.04)	0.03 (0.04)	0.4534
Age						
13–15	0.39 (0.05)	0.3435	0.39 (0.05)	0.38 (0.11)	−0.01 (0.12)	0.9400
16–17	0.30 (0.05)	0.9203	0.29 (0.06)	0.32 (0.09)	0.03 (0.11)	0.7826
18–19	0.31 (0.05)	referent	0.21 (0.05)	0.38 (0.07)	0.17 (0.08)	0.0580

Discussion

This study extends the body of knowledge on the relationship between ETW and the consumption of juices, soft drinks and milk among children living in the United States. It provides weighted estimates based on a nationally representative sample and is different from prior studies that have used small sample sizes, nonprobability samples, and untrained and uncalibrated examiners to diagnose ETW [Levine, 1973; Mungia et al., 2009]. Compared to the overall mean rate of consumption, children with ETW had a somewhat higher mean frequency

of consuming apple juice, orange/grapefruit juice and soft drinks. However, this was not statistically significant.

Studies conducted in the United Kingdom found a significant correlation between the prevalence of dental erosion and the consumption of soft drinks, carbonated beverages, fresh fruits and foods, but suggested that further studies be conducted to confirm this association in other populations [Millward et al., 1994; Milosevic et al., 1997; Al-Dlaigan et al., 2001; Milosevic et al., 2004]. Fruit juice and carbonated soft drinks were found to be associated with ETW in a study of schoolchildren aged 12 conducted in Leicestershire, United Kingdom [Dugmore and Rock, 2004]. We found no association between ETW and soft drinks consumption in our population. Furthermore, Al-Dlaigan et al. [2001] reported that ETW was associated with dietary factors such as consumption of milk and orange juice, but we found no significant association between the consumption of grape, orange/grapefruit, tomato/vegetable juice, juice drinks, soda, or milk, tomato/vegetable juice, soft drinks and ETW. In addition, Barlett et al. [1998] found no association between the intake of carbonated drinks and ETW in 12-year-old children living in London, United Kingdom.

In the multivariable analyses, children who were frequent consumers of apple juice had a higher likelihood of being diagnosed with ETW. This finding is consistent with the results reported by Lussi et al. [1995] in an experimental study. Lussi et al. [1995] reported that apple juice caused the greatest significant decrease in tooth surface microhardness followed by Schweppes, Orangina and grapefruit soft drinks. It is unclear, however, why there was a change in the strength of association and direction within the racial/ethnic group between those with ETW and those without ETW. Compared to Whites, African-Americans had the lowest prevalence of ETW and the highest mean apple juice consumption rate, but the mean difference in apple juice consumption between African-Americans with ETW and those without ETW was in the direction predicted by the individual-level model (though not statistically significant).

Compared to 18- to 19-year-olds, those aged 13–15 years had the lowest prevalence of ETW and the highest mean apple juice consumption rate. However, the mean difference in apple juice consumption between those aged 18–19 years with ETW and those without ETW was only marginally significant, with those with ETW tending to consume apple juice more frequently. This suggests that the race ‘Non-Hispanic Black’ might serve as a protective factor rather than a risk factor for having ETW. These findings highlight the danger of ecological analyses, and also the existence of additional factors beyond drink consumption that could play a substantial role in the etiology of ETW. Further studies are required to throw more light on the relationship between ETW and the consumption of apple juice especially among African-Americans. Direct comparison of our findings with studies on ETW is important and relevant to the body of knowledge on this topic. However, we suggest that researchers interpret these differences and similarities in the context of the age group of participants, diagnostic indices used, sampling methods, and the statistical analyses conducted.

Certain study strengths and limitations should be noted. This study provides empirical evidence to clinicians about the need to carefully review patients’ apple juice drinking habits due to a possible association with ETW. However, this study does not provide information on individual

patterns that might be useful for developing treatment plans for individual patients presenting in a dental office [Nunn, 1996]. Another limitation is that the study did not have information on how the beverages were drunk, for how long and how much per individual patient. In addition, the multivariable analysis adjusted for available covariates, but not for all known potential confounders identified in the literature such as intrinsic acids, saliva condition, tooth brushing and drugs. Beverage consumption was collected via a food frequency questionnaire, and the classification of beverages into categories relied on the information from respondents. Thus the 'apple juice' category can potentially cover a wide range of juices including apple cider, while excluding flavored juices that actually have apple juice as a primary ingredient, if the respondent was unaware of this. Therefore, because of the inherent problems with epidemiological studies of self-reported data we suggest that our study results be interpreted in the context of the limitations stated.

However, with the increased consumption of beverages in North America among children and adolescents there is clearly a need to continue to explore the link between consumption of juices and occurrence/progression of ETW. Although we found that the largest absolute difference in mean apple juice consumption among Blacks was not statistically significant, frequent intake of apple juice was found to be associated with ETW. Future studies are required to identify the possible protective effect exhibited by Blacks and to explore the link between apple juice consumption and ETW from a longitudinal database.

Disclosure Statement

The authors declare that they do not have any conflict of interest.

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