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Association between the number of early carious lesions and diet in children with a high prevalence of caries

ABSTRACT

Aim *An investigation was conducted in a population of paediatric patients with a high risk of caries in order to assess the association between caries history (CH) and the number of early carious lesions (ECLs) and the frequency and timing of cariogenic food and beverage intake, sugar-containing medication, the frequency and efficacy of tooth brushing, and the use of topical fluorides.*

Materials and methods *Study design: descriptive study. One hundred children aged 6-15 years with ≥ ECL of a permanent tooth and not enrolled in any dental health educational or preventive programme were selected. For diagnosis it was used an explorer according to the ICDAS II criteria. The participants completed a closed-list questionnaire on the frequency and timing of cariogenic food intake.*

Results *There was a nonsignificant tendency to present more ECLs and a greater CH among patients who consumed cariogenic foods and beverages. A significant relationship ($p<0.05$) was observed between cariogenic beverages and the number of ECL or CH. Using the number of ECLs as dependent variable, regular fluoridated rinses ($p=0.003$), frequent sugar-containing medication ($p=0.007$), and cariogenic beverage consumption ($p=0.024$) were identified as explanatory parameters in the linear regression model.*

Statistics *The Student t-test was used to compare ECL and CH with dietetic factors, fluoridated rinses, sugar-containing medicines, and the frequency and efficacy of tooth brushing. Linear regression analysis correlated the number of ECLs to the mentioned explanatory variables.*

Conclusion *The frequent consumption of sugary beverages and medications, and failure to regularly use fluoridated rinses, were positively correlated to an increased number of ECLs in patients with a high prevalence of caries.*

Keywords *Early carious lesions; Cariogenic food intake; Oral care habits*

Introduction

Caries is very common throughout the world, though the distribution of the disease is not homogeneous – its prevalence being high or very high in middle and low income countries, and low in countries with a high per capita income [Guido et al., 2011]. On the other hand, caries distribution is also polarised among the so-called developed countries, with a large caries-free population on one hand and a minority group of individuals with increased and more serious caries disease on the other. This makes it necessary to develop tools capable of establishing a diagnosis according to the level of risk [Gao et al., 2010]. A number of factors have been studied as indicators of a high risk of caries, including the consumption of sugary foods and beverages, poor oral hygiene, insufficient topical fluoride use, a personal history of caries, or a low socioeconomic level [Guido et al., 2011]. In view of the multifactorial nature of caries, a number of factors must be considered in order to identify the risk of developing the disease, and these factors in turn exert different influences depending on the age of the individual. Furthermore, among all the risk factors, some have a high predictive value, i.e., they define a situation of high caries risk, such as the presence of active caries or the existence of recent fillings [Ekstrand et al., 2007; Gao et al., 2010]. The hazard posed by diet in relation to caries has classically been attributed to the sugar content of food, as evidenced by many studies over the years. In effect, the literature continues to report a significant association between the consumption of sweet foods and the presence of carious lesions in both the temporary and the permanent dentition [Pita-Fernández et al., 2010]. The existing information moreover suggests a dose-effect relationship between the amount of sugar consumed and the development of caries, at least to a threshold intake of 50-80 g of sugar per day, beyond which the dose-effect curve levels off and a further increase in sugar intake is no longer associated to a further increase in caries. According to Sheiman [2001], the amount of sugar consumed should not exceed 30 g per person and day among children, and 60 g per person and day in adults. The above situation is modified by fluoride use. In effect, in the presence of correct and regular fluoride use, the acceptable amount of sugar consumed increases from 60 to 70 g a day [Sheiham, 2001]. In order to assess the local effect of diet upon the development of carious lesions we must consider all the underlying dietetic factors, i.e., not only the type of carbohydrate consumed but also other parameters such as

the frequency and timing of intake [Young et al., 2010]. Many studies point to the frequency of sugar intake as one of the most important aetiological factors. A more frequent intake of sugared foods gives rise to multiple and prolonged changes in the pH value of dental plaque, with longer effective clearance times. The net result is an increased risk of enamel demineralisation [Hashizume et al., 2011]. Other important dietetic aspects are the timing and sequence of cariogenic food intake, i.e., consumption with or between meals, and the order in which food is consumed, since the cariogenic effects may be modified as a result [Young et al., 2010]. In calculating total sugar intake, we must consider not only the sweet foods and beverages consumed but also the hidden sugars in non-sweet foods, and common medications that contain saccharose, glucose or fructose. In this respect, drug formulations typically contain 2-86% of sugar [Neves et al., 2010], with the purpose of making them more palatable and masking their often bitter taste. Such sugar-containing medicines are particularly common and popular in paediatric formulations, whether prescribed by a physician or administered without a prescription [Pierro et al., 2005]. The sporadic or point use of such medications does not increase the risk of caries – in contrast to their frequent and prolonged administration as treatment for chronic conditions such as allergies, heart problems, epilepsy, asthma, recurrent infections, etc. [Mazzoleni et al., 2008]. The pH of these sugared formulations is usually below the critical pH value, and they moreover prolong oral clearance and can be metabolised by certain oral bacteria, with the resulting production of acids. All these factors give rise to cariogenic and erosive effects [Pierro et al., 2005; Neves et al., 2010]. The decrease in salivation and movements during the night in turn increases the cariogenic potential of these sugar-containing medications when administered at bedtime. The present study investigates the association between caries history (CH) and the number of early carious lesions (ECLs) with the frequency and timing of cariogenic food and beverage intake, sugar-containing medication, the frequency and efficacy of tooth brushing, and the use of topical fluorides in paediatric patients with a high risk of caries.

Material and methods

The present study abides with the Declaration of Helsinki and was previously approved by the Ethics Committee of Valencia University General Hospital (Valencia, Spain) (reference no. 029/2008).

Study population

The study population consisted of children between 6-15 years of age visiting a public Primary Dental Care Unit (Valencia University General Hospital Department, Valencia, Spain) for the first time, in the period between February 2012 and December 2013. The first outcome was to establish the relationship between number of early caries lesions and the frequency of cariogenic food and beverage intake. This outcome was used for sample size calculation. To detect a 15% difference in number of early caries lesions between the patientes with four or more cariogenic intakes a day with 5% significance level, the estimated number of participants required was 100.

A total of 250 patients were evaluated, of which 100 met the inclusion criteria and agreed to participate in the study. The inclusion criteria were: age 6-15 years, first dental visit, and the presence of at least one early carious lesion of a permanent tooth (as evidenced with the tooth moistened and/or air dried for 5 seconds). Patients with diseases or medications capable of modifying salivary flow or plaque microbial composition were excluded, as were those with systemic and/or syndromic diseases. The parents or caregivers were informed of the objectives of the study, and written informed consent was obtained in all cases. The fluoride content of the drinking water of the study population was under 0.7 ppm.

Clinical exploration

All explorations were made in the dental chair with illumination, air/water syringe and aspirator, and using number 5 flat intraoral mirrors (Dentaflux, Madrid, Spain), prophylactic brushes (Premium, Madrid, Spain), and 11.5B periodontal probes (Hu-Friedy, Rotterdam, The Netherlands). A clinical form was designed to collect all the information. The explorations were carried out by a single operator previously trained with the online training program of the International Caries Detection and Assessment System (ICDAS). Five percent of the explorations were repeated in the course of the study in order to assess intraobserver concordance referred to the diagnosis of caries. The resulting Kappa index was 0.90. The following data were collected during the exploration: plaque index according to the criteria of Silness and Löe [Silness and Löe, 1964], and the presence and severity of caries and assessment of dental restorations classified according to the ICDAS II system [Pitts, 2004]. The latter classifies carious lesion severity into 6 groups (1-3 correspond to ECLs, and 4-6 correspond to dentin lesions). Dental restorations in turn are classified into 8 groups. The CAOD and cod indexes were calculated as follows: C = carious lesions corresponding to ICDAS II ≥ 4 and restoration groups 7-8; O = restoration groups 3-6; and A = teeth missing due to caries. The cod index was scored in a similar manner.

Questionnaire

A questionnaire already used in an earlier study [Llena and Forner, 2008] was used to collect information referred to diet. The questions were of a closed-list type in order to avoid failure to mention foods or beverages not perceived as being hazardous but which are nevertheless important for assessing caries risk. The questionnaire was administered by an interviewer and was answered by the child and father, mother or caregiver. The foods contemplated in the questionnaire were grouped as shown in Table 1. We also

documented patient age, gender, medical data of interest, brushing frequency and sources of topical fluoride, in addition to the toothpaste used. The study procedures are schematically presented in Figure 1.

Statistical analysis

The statistical analysis independently considered ECL (i.e., ICDAS II groups 1-3) and CH (calculated as the sum of CAOD, cod and the number of ECLs present). The Student t-test with a level of significance of 95% was used to compare the variables ECL and CH with the frequency of consumption of cariogenic foods, the timing of intake, the use of fluoridated rinses, sugar-containing medicines, and the frequency and efficacy of tooth brushing. Lastly, a linear regression model was developed, using the number of ECLs as dependent variable and the frequency of cariogenic food intake, the timing of intake, plaque index, the use of fluoridated rinses, the frequency of sugar-containing medication, and the frequency of consumption of commercial soft drinks, smoothies and fruit juices, as independent variables. Data were analysed using the SPSS version 19.0 statistical package (IBM Co., Chicago, IL, USA).

Results

Forty-three percent of the patients were males and 57% females, with a mean age of 10.27 years. Forty-four percent of the children claimed to brush their teeth less than once a day, 33% once a day, and 23% two or more times a day. The mean Silness and Löe index was 1.57, representing moderate plaque accumulation. We explored the cariogenic component of the diet based on the number of times which the patient consumed cariogenic foods and beverages per week. Mean consumption was found to be 15.07± 3.21 times a week, representing 2.15±1.74 cariogenic intakes per person and day. On considering food intake outside the 5 main meals of the day (breakfast, mid-morning snack, lunch, afternoon snack and dinner), 61% of the children claimed to never eat between meals, while 4% did so once a week, 6% twice a week, 6% three times a week, 4% four times a week, 3% five times a week, 1% six times a week, and 15% seven times a week. The foods most frequently consumed between meals were sweets (59%), while 41% of the children that ate between meals preferred salted foods. Chocolates, pastry and commercial smoothies and juices were the preferred foods in the mid-morning and afternoon snacks.

The prevalence of caries in our study was 53.2%. The mean CAOD index was 1.56 ± 2.59, and was fundamentally and equally attributable to group C (0.9 ± 1.88) and group O (0.77 ± 1.43), while the remaining 0.1± 0.10 corresponded to group A. The total number of ECLs identified according to the ICDAS II criteria (including groups 1-3) was 1315, with an average of 13.18 ± 4.91 lesions per individual. Of these lesions, 505 were located in pits and fissures, with an average of 5.04±2.54, while the rest were located in smooth surfaces, with an average of 8.13± 4.11. The Student t-test (Table 2) revealed a nonsignificant tendency to present more ECLs and a greater CH among patients who consumed cariogenic foods and beverages. Neither

Food	Timing	Frequency (times a week)
Sweets	Between meals	
	Main meals	
	Mid-morning/afternoon snack	
Juices	Between meals	
	Main meals	
	Mid-morning/afternoon snack	
Smoothies	Between meals	
	Main meals	
	Mid-morning/afternoon snack	
Soft drinks	Between meals	
	Main meals	
	Mid-morning/afternoon snack	
Salty snacks	Between meals	
	Main meals	
	Mid-morning/afternoon snack	
Pastry	Between meals	
	Main meals	
	Mid-morning/afternoon snack	
Industrial bread products	Between meals	
	Main meals	
	Mid-morning/afternoon snack	
Chocolate/ bonbons	Between meals	
	Main meals	
	Mid-morning/afternoon snack	

TABLE 1 Food groups included in the questionnaire.

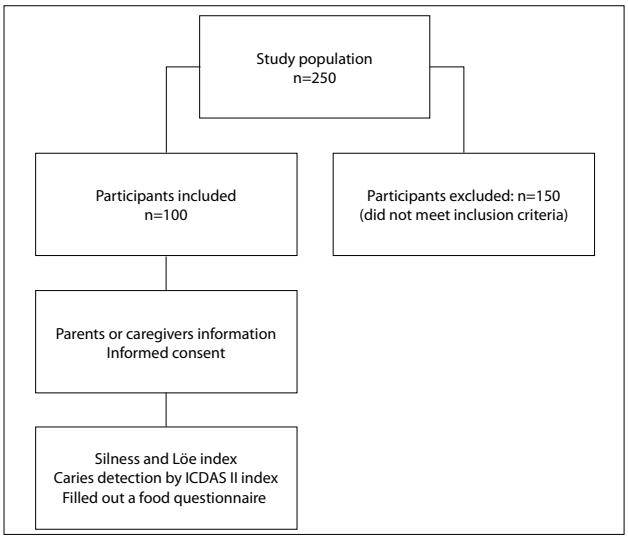

FIG. 1 Schematic representation of the study procedures.

the frequency of consumption of cariogenic foods nor the timing of such consumption was significantly related to either ECL or CH (p>0.05). On considering only the intake of cariogenic beverages, we found the number of ECLs and CH to be significantly greater (p<0.05) in those children that consumed such beverages versus those that did not (Table 2). There was no significant correlation between the number of ECLs or CH and regular tooth brushing. A greater or lesser accumulation of dental plaque was likewise not significantly related to ECL or CH (p>0.05).

On using the number of ECLs as dependent variable in the linear regression analysis, we found the absence of regular fluoridated rinses, the frequent use of sugar-containing medication, and the consumption of cariogenic beverages to explain part of the model (Table 3). Based on the latter, a formula relating the number of ECLs to the explanatory variables could be established as follows: number of ECLs = 3.486 + 3.007 no use of fluoridated rinses + 3.207 frequent use of sugar-containing medication + 0.507 consumption of cariogenic beverages.

Discussion and conclusion

The present study was carried out in patients with a high prevalence of caries visiting a public Primary Dental Care Unit (Valencia University General Hospital Department, Valencia, Spain). The patients were therefore representative of the entire social spectrum, since any child within the studied age range can be attended in such a Unit – including patients from families with limited economic resources, which are less likely to be seen in private practice. Due to their age, cultural diversity and socioeconomic level, these patients are presently the population group at greatest risk of developing carious lesions [Llodra, 2012]. Like in most industrialised countries, the incidence of caries in Spain is low but non-uniformly distributed. [Llodra, 2012]. The reported Spanish national prevalence of caries at 12 years of age is 47%. A Spanish regional study conducted in 2010 reported a prevalence of caries at 12 years of age of 37.7%. [Almerich et al., 2012]. The prevalence of CAOD > 0 recorded in our study was 53.2%, which is higher than the percentage reported by the mentioned national and regional surveys, since ours was a population with a high prevalence of caries. ICDAS II is particularly useful for the early detection of lesions that are still confined to the enamel layer, and classifies lesions visually confined to the enamel as corresponding to groups 1-3, while lesions affecting the dentin correspond to groups 4-6. In addition, the ICDAS II system offers criteria for determining whether the lesion is active or inactive at the time of exploration [Pitts, 2004]. The systematic review conducted by Clara et al. [2012] evidenced the disagreement that exists between the ICDAS II system classification of cavitated lesions and the CAOD index, with the coexistence of two different criteria: presence of a lesion in dentin and presence of a cavitated lesion. These two criteria coincide in ICDAS II groups 5 and 6, but not in group 4, since not

		n	Number of ECLs		n	CH	
			Mean (SD)	p		Mean (SD)	p
Daily intake of cariogenic foods	≤4	95	13.04 (4.82)	0.25	95	15.93 (6.12)	0.28
	>4	5	15.60 (6.65)		5	19 (7.03)	
Cariogenic foods in main meals	No	30	11.77 (4.47)	0.05	30	14.56 (6.03)	0.06
	Yes	79	13.77 (5.08)		79	16.74 (6.14)	
Cariogenic foods between main meals	No	5	13.40 (4.09)	0.91	5	13.8 (4.02)	0.39
	Yes	95	13.16 (4.97)		95	16.21 (6.24)	
Juices, soft drinks and smoothies	No	17	10.30 (4.87)	0.04	17	12.20 (4.61)	0.04
	Yes	83	13.49 (4.84)		83	16.52 (6.217)	
Snacks between meals	No	61	12.74 (4.87)	0.27	61	15.54 (5.66)	0.27
	Yes	39	13.85 (4.92)		39	16.94 (6.85)	
Plaque index	≤1	16	14.94 (5.57)	0.11	16	17.5 (8.27)	0.32
	>1	84	12.83 (4.74)		84	15.82 5.69)	
Daily brushing	≥2	56	12.71 (4.80)	0.29	56	12.71 (6.16)	0.39
	<2	44	13.75 (5.06)		44	16.68 (6.17)	
Use of fluoridated rinses	Yes	31	11.26 (4.79)	0.01	31	15 (6.76)	0.23
		69	14.30 (4.76)		69	16.57 (5.85)	
Frequent use of sugar-containing medication	No	81	12.62 (4.94)	0.02	81	15.71 (6.39)	0.21
	Yes	19	15.53 (4.15)		19	17.68 (4.88)	

The variables significantly associated to the number of early carious lesions (ECLs) and the caries history (CH) are shown in boldface.

TABLE 2 Mean and standard deviation of the number of ECLs and CH according to the variables studied.

	Non-standardised coefficients		Standardised coefficients		
	B	St. error	Beta	t	Sig.
(Constant)	3.486	2.310		1.509	0.135
No use of fluoridated rinse	3.007	0.983	0.284	3.059	0.003
Frequent use of sugar-containing medication	3.207	1.159	0.257	2.767	0.007
Cariogenic beverages	0.507	0.221	0.213	2.291	0.024

TABLE 3 Summary of the linear regression model explaining the number.

all lesions in dentin are cavitated. In our study we used the first of the two criteria, in the same way as in earlier studies [Honkala et al., 2011]. Few studies have examined the risk factors for caries in conjunction with the total carious lesions present. Most publications only address cavitated lesions, assessed by means of the CAOD index. It therefore has not been possible to compare some of our results with those of previous studies. Information on the eating habits of a population and/or individual is essential for designing and implementing interventional programmes adapted to the existing health needs [Llena and Forner, 2010]. In children and adolescents, the diet contributes to both general and buccodental health or disease. Some disease conditions share diet as a common risk factor, including obesity, childhood and juvenile diabetes, and dental caries. Knowledge and control of dietetic habits is therefore important [Guido et al., 2011]. Studies that aim to establish the relationship between eating habits and the development of caries preferentially use frequency of food consumption questionnaires such as that employed in our study. This questionnaire consists of a closed list of foods, and the patient is required to specify the daily, weekly or monthly intake of each of them [Llena and Forner, 2008; Llena and Forner, 2010]. Although questionnaires are the most widely used tool, the data they provide are biased by the fact that the information comes from the patient or accompanying person, and thus might not be completely reliable. As a result, the power of the statistical tests in detecting significant differences may be reduced, and the comparison of different studies may prove difficult. The relationship between the development of carious lesions and dietetic factors has been investigated since the 1940s. Some studies suggest that the relationship between sugar intake and the development of carious lesions is currently different from that documented in past decades, since dental health has improved greatly in the developed countries, with no parallel decrease in the consumption of sugar and cariogenic foods [Serra-Majem et al., 1993]. In our study we observed a nonsignificant tendency towards more ECLs and a greater CH among patients reporting over four cariogenic food intakes a day. Similar results have been reported by other recent studies [Leroy et al., 2005; Pereira et al., 2010; Sankeshwari et al., 2013]. The timing of food intake has been widely studied and is regarded as one of the most important influencing factors in the development of carious lesions. However, attention currently focuses more on the amount of sweet foods and beverages consumed per day than on whether such products are consumed with or between the main meals [Sheiham and James, 2014; Moyniham and Kelly, 2014]. In our study, the timing of intake did not influence the number of ECLs or CH, though there was a tendency towards increased caries disease among those children who consumed larger amounts of cariogenic foods, whether with or between meals. It must be remembered that a number of studies published over the last 15 years in industrialised countries have reported a significant relationship between the consumption of cariogenic food and beverages and the development of cavitated carious lesions [Mattila et al., Källestål and Fjelddahl, 2007; Llena and Forner, 2010]. At present, the accepted role of sugar intake as a key factor in the development of carious lesions appears to have changed, however, particularly in the industrialised world. This may be due to three factors: 1) the relationship between the amount of sugar consumed and the caries index is not linear [Sheiham, 1991]; 2) the fact that the role of sugar may be changing due to the increased consumption of processed starch [Serra et al., 2007; Llena and Forner, 2010; Chankanka et al., 2011; Frazão, 2012]; and 3) the daily supply of topical fluoride in toothpastes and other sources such as oral rinses [Sheiham, 1991; Twetman et al., 2003; Marinho et al., 2004]. In Spain, as in other countries, sugar-containing beverages (packaged juices, carbonated beverages and soft drinks) account for an important part of total sugar intake, especially in children and adolescents [Young et al., 2010]. Moreover, an important increase in the consumption of such beverages has been observed in the last decades. In contrast, the consumption of milk and natural juices has decreased – a fact that has important nutritional implications [Armfield et al., 2013]. Some authors have found the amount and frequency of consumption of packaged juices and soft drinks between meals to be significantly correlated to a high incidence of cavitated carious lesions, with a tendency towards rapid lesion onset and progression [Guido et al., 2011]. Other studies have reported a relationship between caries and the consumption of sweet beverages with meals [Marshall et al., 2003]. In our study, we found the intake of sugared beverages (packaged juices, smoothies and soft drinks) to be significantly associated to the number of ECLs and CH. Vartanian et al. in 2007 conducted a review and meta-analysis of the literature, assessing only the intake of carbonated beverages (i.e., without considering other sugar-containing beverages), and found a positive association to the development of caries [Vartanian et al., 2007].

In calculating the total daily amount of sugars, we must also consider the administration of sugar-containing medications, particularly when these are used to treat children with very recurrent or chronic disorders. In our series we found a positive association between the frequent use of sugar-containing medicines and the number of ECLs. Some studies have found sugar-containing medicines to have a pH below the critical value, which favors calcium and phosphorus depletion from the enamel layer. In addition, the saccharose and glucose contents of such medicinal products are metabolised by the oral bacteria, generating acids that further lower the oral pH value and contribute to enamel demineralisation [Pierro et al., 2005; Gaurí et al., 2011]. However, some in vitro studies have found that sugar-containing medicines cause no greater enamel erosion than sugar-free medicines. The most important predictor of erosion was seen to be the administered dose, with higher doses causing greater enamel erosion [Neves et al., 2010]. A number of countries, such as the United Kingdom, have introduced campaigns aiming to increase awareness among physicians and pharmacists regarding the oral health impact

of sugar-containing medicines, and of the need to produce and prescribe medicinal products containing the same active drug substances but without sugar ingredients. The results of such campaigns have been very promising [Bigeard, 2000]. Many studies have confirmed a strong correlation between tooth brushing and the incidence / prevalence of caries [Leroy et al., 2005; Källestål and Fjelddahl, 2007; Guido et al., 2011; Broffitt et al., 2013].

Regular brushing twice a day has been shown to be very important for controlling the appearance of new carious lesions in children [Ashkenazi et al., 2014]. In our study we observed no association between the number of ECLs or CH and regular brushing or the presence of bacterial plaque. A possible explanation for this is that our patients belonged to a population with a high prevalence of caries, in which proper oral hygiene was not particularly common (only 23% of the children claimed to brush their teeth at least twice a day). The regular supply of fluoride in toothpaste is known to exert a cariostatic effect, inhibiting enamel demineralisation and promoting remineralisation [Miller et al., 2012]. At present, over 95% of all marketed toothpastes are fluoridated – a fact that is considered to be important for oral health and capable of reducing the incidence of caries in permanent teeth by up to 24% [Twetman et al., 2003]. A meta-analysis of the studies published up until 2002 [Marinho et al., 2003] concluded that fluoride in toothpastes is effective in preventing caries in all age groups. However, the study also found the effectiveness of fluoridated toothpastes to be conditioned by patient, family and population behaviour and habits regarding the purchase and use of such toothpastes. This may have influenced the results obtained in the present study. Although toothpaste is the most widely employed vehicle for supplying fluoride, the use of oral rinses is also very common in our setting. We observed an inverse correlation between daily or weekly fluoridated oral rinsing and the number of ECLs. This is consistent with the findings of a meta-analysis in which the use of a fluoride source in the form of rinses, gels or varnishes, in addition to a fluoridated toothpaste, was seen to offer greater benefits than the use of fluoridated toothpaste alone [Marinho et al., 2004].

It can be concluded that under the conditions of the present study, involving patients with a high prevalence of caries, the frequent consumption of sugar-containing beverages and medicines, and failure to regularly use fluoridated supplements, are associated to an increased number of carious lesions. However, the frequency and timing of the consumption of sweet foods and sugar-containing beverages during the day, and the frequency and efficacy of tooth brushing, are not significantly associated to the number of carious lesions. Caries is the most common chronic disorder in children, with important individual and social costs, and an impact upon patient quality of life. In this context, the role of sugar-containing foods and beverages as risk factors for the development of carious lesions should be taken into account and used by health professionals and the communications media to offer advice on how to preserve a healthy and caries-free mouth during childhood and adolescence.

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