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Sugar before bed: a simple dietary risk factor for caries experience

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Clinical care pathways have placed renewed emphasis on caries risk assessment and the ability to predict and prevent further disease. With diet considered a key factor in the development of caries, the level of caries risk posed by dietary habits, such as the frequency of intake and timing of free sugars is questioned. ***Objective:*** To identify reliable and simple dietary risk factors for caries experience. ***Research Design:*** A cross-sectional observational study of a convenience sample with data gained from clinical examinations, questionnaire and a 24 hour dietary-recall interview. ***Participants:*** 128 subjects aged 11-12 from comprehensive schools in Greater Manchester and Newcastle-upon-Tyne, UK. ***Outcome measures:*** free sugars consumed between meals, before bed and total % of total free sugars consumed were assessed from dietary assessments led by a dietitian. D_{4-6}MFT was generated with a caries threshold of ICDAS stage 4 from clinical examinations. ***Results:*** Analysis revealed no significant differences in caries experience when looking specifically at caries into dentine, referred to as the cavity group (split at D_{4-6}MFT), between high and low deprivation, consumption of free sugars between meals and free sugars (%). The consumption of free sugars within the hour before bed revealed a statistically significant difference between the cavity/no cavity groups (p=0.002). Logistic regression analysis on the cavity/no cavity groups revealed an odds ratio of 2.4 (95%CI 1.3,4.4) for free sugars consumption before bedtime. ***Conclusions:*** The study suggests that the consumption of free sugars before bedtime may be an important risk factor for adolescent caries into dentine experience.

Key words: *dental caries, diet, dental cavity, sugars, snacks, UK*

Introduction

Dental caries is a preventable chronic disease; yet it still remains prevalent in children. Untreated caries in the primary dentition is a common condition globally (Marcenes *et al*., 2013) with an estimated 60-90% of school children worldwide experiencing dental caries (Petersen *et al*., 2005). The development of robust methods for risk assessment and prevention, are a priority owing to painful, infected teeth, but also potential impacts on health in later life (Graham and Power, 2004). However, this is a complex issue given the multi-factorial nature of caries risk. Consideration of these factors is needed to facilitate advice and intervention strategies with the aim of preventing future caries.

There are two distinct philosophies emerging for prevention on a dental public health level: the population based approach and the risk assessment based approach (Milsom and Tickle, 2010). The risk assessment approach is argued to be a more sensible strategy to target interventions at those who need it. This has the benefit of greater cost effectiveness as compared to the population approach. However, the success of the risk assessment model is reliant on the accurate prediction of caries risk and as yet, there is no reliable tool for predicting caries (Milsom and Tickle, 2010). Reliable predictors are therefore needed, validated by evidence-based research, to assist in the risk assessment of caries.

Free sugar intake is an important aetiological factor to consider in caries risk assessment (Flinck *et al*., 1999), but is difficult to assess and quantify. Various methods have been used to assess diet such as diaries (Kidd and Fejerskov, 2005), 24-hour recall interviews (Ziegler *et al*., 2006), diet histories and food frequency questionnaires (FFQs) (Brown, 2006). Ziegler discussed the various methods for collecting dietary data (as described above). While each method has both limitations and benefits, the selection of data collection methods is dependent on the focus of the study. Discussion centres on the specialist knowledge/additional training needed in order to carry certain data collection, the onerous nature of some of the methods and the need for cooperation and motivation to provide a truthful record (Moynihan *et al*., 2009; Ziegler *et al*., 2006). While detailed, well-conducted research on nutrition is important within oral health research, significant issues exist in both research and clinical settings. It may be valuable, particularly within a clinical setting, in performing a risk assessment with a simple direct question relating to a known caries risk factor. This information could facilitate the decision whether further information is necessary, particularly as dietary advice is rarely provided by dental practitioners (Franki *et al*., 2014). Or it could be used within larger epidemiological pieces alongside other known risk indicators related to caries experience.

The role of dietary sugars in the development of caries has been well established, particularly the damaging impact of free sugars (Moynihan and Kelly, 2014).

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Consequently, the importance of good dietary habits has been promoted by professionals and on a wider scale through government initiatives and policy. The Oral Health Toolkit echoes long-standing advice by recommending the reduction in the frequency and amount of sugary food and drinks (PHE, 2014). Sugar consumed before bed increases caries risk due to a diminished saliva rate causing sustained low plaque pH levels. This is supported by a significant relationship in caries experience and the consumption of free sugars one hour before bed (Levine *et al*., 2007).

The emergence of clinical care pathways has placed renewed emphasis on risk assessment to help predict further disease and guide future prevention and intervention strategies (NICE, 2004). It is possible a simple direct dietary question on sugar consumed an hour before bed would give a practical alternative to extended questionnaires, which are not always accurate and are fraught with issues such as responder fatigue. Thus the main aim of this study was to determine the influence of food consumption prior to bed on the caries status (cavitation) of adolescents thus allowing dentists to give 'chair-side' advice to children and families

Method

This cross-sectional, observational study involved 128 healthy male and female subjects aged 12-13 from comprehensive schools in the cities Manchester and Newcastle-upon-Tyne (Newcastle). All participants were recruited from an on-going cross-sectional study into the effect of social deprivation, prevalence of caries and fluorosis in fluoridated and non-fluoridated areas (McGrady *et al*., 2012).

Schools were selected based on their uptake of free school meals as a measure of social deprivation (Muirhead and Marcenes, 2004; Shuttleworth, 1995) and an expectation of high lifetime residency status for the children. A total of 13 schools were used: 10 from Newcastle (fluoridated area) and three from Manchester (non-fluoridated area).

Ethical approval was granted from the University of Manchester Ethical committee (ref: 07052). Postcodes were used to arrive at a measure of relative deprivation through the use of the Index of Multiple Deprivation (IMD).

The two examinations collecting the data for this study were carried out over two school visits. The first visit involved a clinical caries examination led by a dentist and the second visit involved dietary assessments led by a dietitian.

Clinical examination was carried out with the use of a dental operatory light and dental unit equipped with compressed air, was carried out by a dentally trained clinical examiner using the International Caries Detection and Assessment System (ICDAS). All teeth present were examined. The variable $D_{4\text{-}6}MFT$ was generated with a caries threshold of ICDAS 4 for the decayed teeth component, missing teeth noted as those teeth extracted due to caries (unless known to have been extracted for orthodontic reasons) and filled teeth with clinically visible restorations were recorded.

All subjects were given a short questionnaire on toothbrushing and a three-day food diary together with written and verbal instructions for completion. Importance of recording all food and drink consumption over the three-day period (including a weekend day) was stressed. Of the subjects who returned a completed food diary, a sample was chosen for further detailed dietary analysis based on subject consent, and logistical considerations such as school cooperation and available time.

These dietary assessments were conducted by a dietitian and a trained nutrition assistant during a visit to the school. A 24 hour recall was conducted in conjunction with the three day food diary to confirm and re-asses the information entered into the diary and capture as much of the 'free sugars' in the diet as possible.

To ensure all possible drinks and snacks consumed in the last 24 hours were recorded, participants were prompted about food, drinks and snacks (containing free sugars) related to the activities they were doing and who they were with. It was hoped this would help record the food/drink intake more precisely. Free sugars were defined as 'added sugars' most damaging to dental health, such as sucrose, glucose, fructose. This excluded natural sugars present in milk, fruit and vegetables. Percentage of calories derived from free sugars were calculated and are referred to as % free sugars throughout this paper.

Any foods or drinks consumed which contained free sugars were recorded as a positive intake. Tinuviel V3 was used to analyse the dietary data, which includes food where juices, honey and syrup are consumed. This was recorded when doing both the 24-hour recalls and three-day food diary.

Data analysis was performed using SPSS, including; t-tests, Mann Whitney U and chi-square analysis where appropriate. Logistic regression and odds ratio estimation was used to determine if any dietary habits predicted caries experience. The level of statistical significance was set at $p=0.05$.

Results

There were 128 subjects included for statistical analysis in this study: 51% from Newcastle (a fluoridated area), 49% from Manchester (a non-fluoridated area). The difference in deprivation between the Manchester and Newcastle subjects was marginally significant ($t(126)=-2.011$, $p=0.046$, $r=0.18$) whereas analysis on age indicated evidence of a difference between cities ($t=-5.720$, $p<0.0001$, $r=0.45$) (Table 1). However, given the age difference was only approximately five months it is not thought to be a concern in relation to further analysis. In fact, a difference of this size could have been expected given the time period to interview and collect data from school groups over the school year. Given the primary objective of this element of the research was not to compare cities, but to develop a risk assessment tool, the differences are not believed to be relevant and the groups are sufficiently homogenous to continue analysis.

Table 1. Gender, age and deprivation status of the subjects and their frequency across Manchester and Newcastle

	Overall	*Newcastle*	*Manchester*	*p value*
Total subjects, n (%)	128	65 (51%)	63 (49%)	
Male, n (%)	68 (53%)	33 (51%)	35 (56%)	
Female, n (%)	60 (47%)	32 (49%)	28 (44%)	χ^2 (1)=0.294, P=0.587,
IMD, mean (95%CI)	39.1 (35.4, 42.8)	35.4 (29.8, 41.1)	42.9 (38.2, 47.5)	t (126)=-2.011, P=0.046, r=0.18 [1]
Age at exam, mean yrs (95%CI)	12.8 (12.8, 12.8)	12.6 (12.5, 12.7)	13.0 (12.9, 13.1)	t=-5.72, P<0.0001, r=0.45
Free sugars between meals	2	2.0	2.0	0.776
Free sugars before bed	0	0.0	0.0	0.874
% Free sugars	18.9	16.2	21.1	0.017

[1] Independent t- test conducted when analysing age and IMD between cities as all assumptions for parametric tests were met. Mann Whitney U was conducted for free sugars consumption as assumptions were not met.

Table 2. Comparisons of dietary intake of free sugars and deprivation status with caries experience ($D_{4-6}MFT$)

	Total	*Caries dichotomised $D_{4-6}MFT$*		*p value*
		No Caries ($<D_{4-6}MFT$)	*Caries ($>D_{4-6}MFT$)*	
Total subjects, n (%)	128	65 (51%)	63 (49%)	
IMD, mean (95% CI)	39.1 (35.4,42.8)	36.9 (31.8,42.0)	42.1 (36.7,47.4)	t (126)= -1.375, p=0.172,
Age at exam, mean (95% CI)	12.8 (12.8,12.8)	12.7 (12.6,12.8)	12.9 (12.8,13.0)	t=-2.573, P=0.011, r=0.22
Free sugars between meals	2	2	2	P=0.422
Free sugars before bed	0	0	1	U=2,331, z=1.607, P=0.002, r=0.14
% free sugars	18.9	17.8	20.2	P=0.108

Note: Assumptions for parametric tests were met for IMD and age but not for free sugars consumed, appropriate tests were carried out based on this information and median presented

Table 3. Logistic regression analysis of free sugars before bed and caries experience ($D_{4-6}MFT$), n=128

	B (SE)	*Wald*	*Odds Ratio*	*95% CI*	*p*
Constant	-11.1 (6.5)	3.1			
Age at exam	0.8 (0.5)	2.5	2.3	0.8,6.3	0.114
Free sugars before bed	1.3 (0.4)	9.9	3.6	1.6,8.2	0.002
Smear vs. other toothpaste amount	-0.4 (0.7)	0.3	0.7	0.1,2.8	0.597
Large pea vs. other toothpaste amount	-0.2 (0.8)	0.1	0.8	0.2,3.6	0.794
Full brush head vs. other toothpaste amount	-0.9 (0.8)	1.5	0.4	0.1,1.8	0.222
Non-fluoridated area	0.9 (0.5)	4.5	2.6	1.1,6.5	0.035

Note: R^2= 0.804 (Hosmer-Lemeshow), 0.169 (Cox & Snell), 0.227 (Nagelkerke).

On average, subjects in Manchester and Newcastle showed no significant difference in the amount of free sugars they consumed (number of times sugars are taken) between meals or before bed (see Table 1). There was evidence of a greater percentage of total calories composed of free sugars in Manchester than in Newcastle (Median 21.1 vs. 16.2, U=2,549, z=2.390, p=0.017).

Differences in caries experience between fluoridated and non-fluoridated areas were not thought to inhibit further analysis looking at caries experience and sugar consumption. After combining the subject numbers from Manchester and Newcastle, 42% were found to have caries at the $D_{4-6}MFT$ threshold (Table 2). There was no significant difference in caries experience when looking at IMD, free sugars between meals and percentage of total calorific intake composed of free sugars. The only dietary variable that showed a significant difference when looking at caries experience was free sugars before bed (U=2,331, z=1.607, p=0.002, r=0.14).

Logistic regression analysis identified the frequency of free sugars snacks consumed before bed as a predictor of caries experience, with an odds ratio of 3.6 (Table 3). The original model correctly classified 58% of caries experience in the children studied this rose to 71% with the addition of sugar before bed, age at exam variable, receiving fluoridated water and brushing data (amount of toothpaste used). R^2 indicates a small improvement of the full model over the intercept model.

The mean $D_{4-6}MFT$ for subjects who consumed at least one free sugars snack before bed was over double that of those who did not 1.5 (SD 1.7) vs. 0.7 (SD 1.1) (U=2,550, z=3.369, p=0.001, r=0.30).

Of the 49 subjects who consumed free sugars before bed, most (84%) also had free sugars snacks during the day (Table 4). However, of the 109 subjects who consumed free sugars snacks during the day, most (62%) did not consume free sugars before bed. Only 11 subjects (9% of the total sample) did not have free sugars snacks during the day or before bed (Table 4). The percentage of calories from free sugars was not significantly different in those children who consumed sugar in the hour before bed and those who did not (19.8% vs. 18.8%), indicating that bed time sugar was not simply a proxy for overall sugar consumption (Table 5).

Table 4. A contingency table of subjects who consumed free sugars before bed and between meals

		Consumed free sugar snacks between meals								
		Counts in the above category			*% within free sugars before bed*			*% within free sugar snacks between meals*		
		No	*Yes*	*Overall*	*No*	*Yes*	*Overall*	*No*	*Yes*	*Overall*
Consumed free sugars before bed	*No*	11	68	79	13.9%	86.1%	100%	57.9%	62.4%	61.7%
	Yes	8	41	49	16.3%	83.7%	100%	42.1%	37.6%	38.3%
	Overall	19	109	128	14.8%	85.2%	100%	100 %	100 %	100 %

Table 5. Estimated dietary free sugar percentages for consumption of and abstinence from sugars before bedtime and between meals

	% free sugars (SD)		*Significance*
	Yes	*No*	
Sugar within an hour before bed	19.8 (8.6)	18.8 (11.5)	U=2,244, z=1.512, p=0.130 non-sig.
Sugar between meals	19.6 (11.6)	13.3 (10.6)	U=1,476, z=2.952, p=0.003, r=0.26

Discussion

This study investigated the influence of free sugars consumed on the caries status (cavitation) in adolescents. The only factor to emerge with a significant relationship to caries experience was free sugars consumption an hour before bed.

Cariogenic dietary habits provide important causative risk factors for caries but due to the multifactorial aetiology of the disease, it can be difficult to single out specific factors to predict a significant proportion of the observed caries experience. It is interesting therefore, that this study found the frequency of free sugars snacks before bed was associated with caries experience in the subjects sampled with an odds ratio of 2.395.

Caution should be taken in drawing any definitive conclusions from these results due to several limitations and confounding factors. The overall sample size was only 128, of which 54 subjects had caries. This places limitations on the validity of the predictive relationship of free sugars consumption before bed was shown to have. Nevertheless, in light of these preliminary findings, it could be worthwhile to explore this relationship on a larger scale.

Dietary assessments such as the 24-hour recall interview used in this study rely on self-reported data. The reliability of this is dependent on the subject's cooperation and motivation to provide a truthful record. There are several potential limitations such as recall bias, embellishment and the possibility of atypical dietary intakes. As dietary assessments were carried out after clinical examinations this could have created some bias in dietary reporting if the clinical exam raised oral health awareness in the subjects. Cross-sectional studies using 'snap-shot' dietary assessments such as the 24 hour recall should always be taken with caution when comparing it to DMFT as a measure of lifetime caries experience, where the assumption is that diets have not changed over several years previously. A longitudinal study design would help to overcome this limitation of the cross-sectional approach, however this would considerably increase the time and expense of the study. This is a major concern particularly within epidemiological studies and hence the need for a rapid, simple and reliable tool in relation to diet and caries risk (Rugg-Gunn *et al*., 1984).

Three-day food diaries were used in this study, however there was poor cooperation with their use with many diaries not returned or returned incomplete/illegible, highlighting limitations in this age group relating to cooperation. They did however help stimulate a discussion of dietary intake at the 24-hour recall assessment. Appropriately completed food diaries may provide an effective tool in establishing individual dietary intake, thereby facilitating tailored dietary advice. Despite being time consuming and labour intensive to complete and analyse, the potential benefit of food diaries to aid tailored dietary advice relevant to the individual cannot be ignored. In fact it is recommended in the 'Delivering Better Oral Health' toolkit around diet modification (BASCD, 2009).

The presence of fluoridated water in Newcastle subjects may have caused the true effect of cariogenic dietary habits on caries experience to be underestimated. On comparing the two populations of Manchester and Newcastle, which differed in their fluoridation status, a borderline significant difference was detected in deprivation, but insufficient to deter further analysis combining the groups. The percentage free sugars consumed in Manchester were noted as significantly higher. However, this did not seem to impact on dietary habits of free sugars snacks between meals and bedtime consumption of free sugars, with no evidence of a difference between the two populations.

Although consumption of free sugars before bed was shown to be associated with caries experience, it is appreciated bedtime intake may be part of a general pattern of increased free sugars intake. The caries experience of the sample might be explained by this overall increased frequency of free sugars intake and not just free sugars consumed before bed. However, the majority of subjects who consumed free sugars during the day were found not to consume free sugars before bed (62%). With this in mind, the fact free sugars snacks during the day was not found to significantly predict caries experience suggests free sugars consumption at night is possibly a more important determinant of caries experience further indicating this method may be a good indicator of diet as opposed to only looking at snacking during the day.

Diet analysis with regards to caries risk assessment can become a time consuming process. Identifying key risk factors to predict caries experience, can allow practitioners to focus their time on relevant risk assessment questions. Although there is debate over a population-based approach versus a risk-based approach to caries prevention (Milsom and Tickle, 2010; Page *et al*., 2010), risk-based approaches such as dental recall intervals advocated by the National Institute of Clinical Effectiveness (NICE, 2004) being likely to continue due to their advantage of greater cost effectiveness. Reliable predictors are needed for risk assessments to be valid enough to identify high-risk patients. Currently, the only accepted accurate predictor of risk is evidence of current or previous caries experience (Hausen, 2008), which is unfortunate as this predictor of future disease requires the existence of caries resulting from the failure of prevention strategies. Asking a simple question about sugar before bedtime could be used for both population and individual risk based assessments. Identifying dietary habits as predictors of caries risk at an early stage could provide an opportunity for children and parents to be educated about harmful effects and change detrimental habits before irreversible damage is caused.

The significant relationship of bedtime consumption of free sugars and caries experience reported in this study is consistent with other studies (Levine *et al*., 2007) and fits with information given through 'The Scientific Basis of Oral Health Education' around avoiding free sugars before bedtime (Levine and Stillman-Lowe, 2014). The additional finding was the DMFT increment for subjects consuming at least one sugar snack before bed was over twice that of others supporting the findings of a previous study into bedtime consumption of sugary snacks (Levine, 2007). Although differences in the study designs are noted such as the criteria for the caries increment, these thresholds are similar in that dentine involvement is seen in both and does not detract from the similar trend shown in both studies of a positive relationship between caries experience and bedtime free sugars consumption.

Conclusion

Within the limitations of this study, consumption of free sugars before bedtime has been shown to be an important risk factor for cavitated lesions in adolescent children. Therefore, this may be a suitable alternative to more time consuming, yet comprehensive, questionnaires particularly in a practice setting where a dentist or other health professional may need to make an initial rapid assessment before commencing further investigation and potential prevention. We are not advocating this abbreviated measure replaces a more comprehensive diet assessment processes in clinical or research activity – however, these initial results demonstrate there is a role to play in pragmatic assessments of diet with high levels of completion when compared to, for example, diet diaries. Additionally, it can be used for simple and easy to follow advice to aid the prevention of caries, i.e. if children are at high risk of caries and require rapid action to assist disease stabilisation, prior to more extensive dietary investigation. The results should be interpreted with a degree of caution due to a low sample size and low caries experience in the sample population; further research is needed with a larger population in order validate the preliminary findings from this study. The results however are consistent with previous studies and supports advice promoted by Levine for a 'sugar free zone' in the hour before bed as a recommendation for the prevention of caries (Levine, 2007). It is important, however, when providing advice to patients and populations that total intake of free sugars should be reduced as part of a holistic plan for oral and general health.

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