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ORIGINAL ARTICLE

The Study of Cariogenicity of Raw Sugarcane in 12-year-old Children in Punjab, India

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ABSTRACT

There is laboratory evidence that refined carbohydrates are more cariogenic compared with unrefined carbohydrates. It was reported that sugarcane workers in South Africa, who consumed large quantities of raw sugarcane daily, had a low caries experience. However, other epidemiologic studies of this relationship, both in Africa and elsewhere, have given mixed results and to date the question concerning the cariogenicity of raw sugarcane remains equivocal.

Objective: The purpose of the present study was to investigate further the hypothesis that children who reside in a sugarcane growing region have a lower caries experience than those residing in an otherwise comparable environment outside of the sugarcane growing region.

Method: A total of 404 Children aged 12 years were selected from government run schools in both sugarcane region which was close to the town of Mehta and non-sugarcane region which was close to attari in Amritsar district in the state of Punjab, India, and were given consent to participate in the survey. Data on the eating habits of the children were obtained by questionnaire and caries experience was determined during a clinical examination. The drinking water in both regions contained fluoride at less than 0.5 ppm.

Results: The mean DMFT scores for the sugarcane and non-sugarcane groups were 0.41 and 0.70, respectively ($p<0.002$). In a multivariable logistic regression analysis of risk factors for a caries experience, residence area alone was the sole significant predictor of experiencing one or more DMFT. Children residing in the sugarcane growing region were 49% less likely to have decayed teeth (OR=0.51; 95%CI= 0.33, 0.78).

Conclusion: The null hypothesis is rejected; the results of this study support the hypothesis that the chewing of raw sugarcane is associated with reduced dental caries experience.

Keywords: Caries, coronal, Diet

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INTRODUCTION

On the basis of an examination of skulls dating from the bronze-age onwards, Hardwick demonstrated that dental caries was rare in England and that its prevalence fluctuated with rises and falls in cereal production (1). At that time, lesions were confined mainly to cervical margins whereas coronal caries did not generally occur until sugar came into common usage in the 17th century. Several 20th century studies of remote hunting communities have detailed dramatic rises in caries experience coinciding with diet changes following a sudden exposure to foodstuffs containing flour and sugar (2, 3).

Prior to the development of an understanding of the role of fluoride in caries prevention, research on caries aetiology and management strategies centred on the diet-caries relationship and confirmed that the upsurge in sugar consumption was mainly responsible for the caries pandemic that swept western cultures during the first half

of the 20th century (4). The acid theory of dental caries aetiology was first postulated by Miller (1890), who demonstrated that when extracted teeth were incubated in a mixture of saliva and carbohydrate, they were subject to demineralization (5). In 1937, Osborne and Noriskin (6) reported on the low caries experience of sugarcane cutters in South Africa in a region where the fluoride concentration in the drinking water was less than 0.1 mg/L. These workers chewed up several sugarcane sticks daily and consumed large quantities of sugarcane juice. On average, they consumed 4.5kg of sugarcane daily (500gm sucrose) (7). Osborn *et al.* (8) demonstrated via *in vitro* studies that the incubation of mixtures of saliva and pure sucrose readily results in the production of organic acids and that the addition of teeth or calcium phosphate to these mixtures results in their dissolution. On the other hand, when such experiments are repeated in which pure sucrose is replaced with raw sugarcane juice, the dissolution does not occur despite the acidic environment. It was postulated that phosphates, which are removed during the sugar refining process, are protective against dental caries (9), yet it was later shown that, in fact, the acid yield on fermentation of unrefined carbohydrate was about double that derived from the refined products (10). At the same time, the greater quantity of acid produced did not correspond with a greater capacity to demineralise tooth enamel.

Animal studies demonstrate that dietary phosphate additives are protective against experimentally induced caries (11), but epidemiologic studies of caries experience in sugarcane chewers (Table 1), that have been cited in relation to the hypothesis that consumption of raw sugarcane is protective against caries, give mixed results (12).

Possible support for a protective effect was reported more recently among 100 Tanzanian 12-year-olds living on a sugarcane estate (13). Caries experience there was reported to be similar to that of other rural and urban Tanzanian children examined by the same authors (14, 15), but it was also reported that workers at the sugarcane estate received refined sugar as a work incentive, and that refined sugar consumption by the estate population was six times higher than the national average. Had it not been for the possible protective effect of sugarcane chewing, it might have been expected that the caries experience of the estate children would be higher than among children from elsewhere.

Support for a sugarcane-related protective effect was shown in Australia (16) where a controlled cohort study was conducted among 399 boarding school children to investigate the effect of supplementing dietary sugar with calcium sucrose phosphate, the organic phosphate which is presumed to be removed from sugarcane during the refining process. Children attending the control schools followed their usual diet while those belonging to the experimental schools were exposed to a diet in which the added sugar was supplemented with calcium sucrose phosphate. After three years, the DMFT, DMFS, and proximal surface DMFS were 15.3, 17.9, and 29.5% less in the experimental children aged 9-13 years compared with the control children of the same age. While these results appear impressive, Craig (17) reported that during the course of the study, the groups became unbalanced and that the results could be biased. A more recent *in vivo* study of Kenyan children, aged 7-14 years, with cavitated teeth confirmed the anti-cariogenic potential of chewing sugarcane (18). On one day, they rinsed with 10% pure sucrose and on the next day they chewed sugarcane for 3 minutes. Measurements at interproximal sites on both days showed that pH falls following sucrose rinses were deeper than those following the chewing of sugarcane. Further, the depressed pH, induced by the sucrose exposure, took longer than 30 minutes to return to baseline levels compared with return times of 5-10 minutes following sugarcane chewing. It was concluded, however, that the result was probably not due to a protective factor derived from the sugarcane but that the rapid pH rise was a natural result of an increased saliva flow rate which was stimulated by the combination of the sweet sugarcane juice and the vigorous chewing action required to masticate the tough cane.

On the other hand, in Cuba (19), where brown sugar is used extensively in cooking and for food seasoning, extensive caries experience and tooth loss was reported among sugarcane workers. This study did not, however, include non-sugarcane eating controls, nor was the dietary added sugar controlled for. The results of another cross sectional study of sugarcane consumption among Tanzanian children aged 7 to 15 years failed to demonstrate a correlation with caries experience, however it is not clear whether either age-related consumption of sugarcane or age-related caries experience was controlled for in this study (20). In yet another controlled cross sectional study of adults, also conducted in Tanzania, a caries protective effect among 77 cane cutters was not evident (21). In this study, the caries experience of 68 sisal labourers was also investigated. Although the ratio of sugarcane consumption by the cane cutters and the sisal labourers was 10:1, the diets of both groups were otherwise said to be comparable and low in refined carbohydrates. The respective mean DMFS scores of the sugarcane and sisal workers were 13.9 and 7.8.

The purpose of the present study was to investigate further the hypothesis that children who reside in a sugarcane-growing region have a lower caries experience than those residing in an otherwise comparable environment outside of the cane-growing region.

METHODS

The chewing of sugarcane by children in the state of Punjab, India, occurs during two periods each year totalling about 6 months when the cane is harvested. This survey of 12-year-old children attending government run schools was conducted in the Amritsar District of Punjab. The selected schools were located in villages surrounding a sugar mill, close to the town of Mehta in the sugarcane belt along the Beas River. Parents of children attending the seven largest government run village schools in this area were requested to give consent for their 12-year-olds to participate.

Table 1: Summary of studies investigating the possible anticariogenic effect of raw sugarcane chewing

First author	Study type	Location	Method and results	Support[1]	Comment
Osborn (7)	In vitro	South Africa	32 teeth were added to each of mixtures of saliva and (a) crude sugarcane juice (15% sucrose) and (b) refined pure sugar solution (15% sucrose). After 8 weeks incubation, 3 and 15 teeth in solutions (a) and (b) respectively were decalicifed	Yes	
Driesen (18)	Cross sectional	Cuba	Study of 147 sugarcane cutters who chewed and drank large quantities of sugarcane juice daily. Crude brown sugar was also used extensively in cooking and for food seasoning. Mean DMFT was 15.1, 10 were edentuolous, and 1 was caries free.	No	No control for non-cane cutters and other sugar use
Jenkins (22)	In vitro	United Kingdom	50 mg calcium phosphate mixed with 7 ml saliva was added to each of 5 mls of (a) sugarcane juice (20% sucrose) and (b) pure sucrose solution (20% sucrose). After incubation for 24 hours, the concentration of phosphate in solutions (a) and (b) increased by 9 and 79 micrograms/ml, respectively.	Yes	
Harris R (15)	Controlled cohort	Australia	Boarding school children aged 9-13 years were exposed to (a) diet in which calcium sucrose phosphate was substituted for dietary sugar and (b) normal diet. Comapred with children on diet (b) scores for DMFT, DMFS, and DMFS (proximal surfaces) were less by 15.3%,17.9% and 29.5%, respectively.	Yes	
Harris S (6)	Cross sectional	South Africa	Study of 98 male and female sugarcane chewers aged 14->60 years. Their daily mean consumption of sugarcane was 4.5kg (500gm sucrose) Normal diet comprised maize, legumes, meat, and water (< 0.1 ppm F). DMFT scores for adolescents, young adults, middle and old age groups were: 0.9, 3.1, 6.0, and 8.1, respectively.	Yes	High intake of sucrose and low caries experince hints at protective effect.
Nörmark (19)	Cross sectional	Tanzania	Study of 399 children aged 7-15 years. The distribution of DMFS by sugarcane was random	No	No control for age.
Frencken (20)	Cross sectional controlled	Tanzania	Study of (a) 77 sugarcane cutters and (b) 68 sisal labourers. Diets,said to be comparable, included 4gm of refined sugar daily. The ratio of daily sugarcane eaten (a):(b) was 8.1:0.8. DMFS for (a) and (b) were 13.9 and 7.8, respectively.	No	
Rugarambu(12)	Cross sectional	Tanzania	Study of 100 sugarcane estate children aged 12 years, where estate consumption of refined sugar was 6 times higher than the national average. Mean DMFT of 0.48 was comparable to scores of 0.51 and 0.67 for other rural and urban 12-year-olds, respectively.	Possible	Sugarcane chewing may have counter-acted the effect of exposure to refined sugar.
Fejerskov (17)	Experimental cross over	Kenya	Study of children aged 7-14 years with 2 or more open cavities . On day 1, they rinsed with 10% sucrose solution, and on day 2, chewed sugar cane for 3 minutes. Plaque pH was measured at non-carious proximal sites before and up to 30 minutes following both rinsing and chewing. After rinsing with sucrose solution, pH values recovered after 30 minutes, but fell less and recovered in 5-10 minutes following chewing sugarcane.	Yes	

1. Support for hypothesis that raw sugarcane chewing is anticariogenic.

Similarly, consent was obtained from parents of the reference children who attended the six largest government run schools in villages around Attari, a non-sugarcane growing region. Attari is a small town, 50 km southwest of Mehta, near the border with Pakistan. Apart from the difference in exposure to sugarcane, the population samples were similar in other respects. Only children of lower socio-economic groups attend government run schools in Punjab. In both areas, the fluoride concentration in the drinking water was less than 0.5 mg/L. Families subsist on their land from one generation to the next, so that the children examined were life-long residents of their respective areas. Although the children in both regions were either Sikhs (the majority) or Hindus, they live in rural villages and share the same cultural beliefs and practises; in particular, their diets are the same.

At the selected schools, the children were interviewed using a structured questionnaire to obtain information on their diet and tooth brushing habits. This was followed by clinical examinations which were conducted outside in natural daylight by a single examiner who had been calibrated before the survey. The children, none of whom had experienced previous dental care, were seated on a chair and their teeth were examined with the aid of a wooden spatula but without drying. Caries was diagnosed by visual inspection alone whereby teeth were recorded as decayed on the evidence of presence of cavitation (22). The data were later entered into an electronic database for subsequent statistical analysis. Intra-examiner calibration was carried out during return visits to two schools in each region where randomly selected children were re-examined under the same conditions as previously.

Following data checking, the mean DMFT scores of children in the two locations were calculated and compared. The effect of potential confounding variables on the relationship between sugarcane chewing and dental caries experience was assessed. Firstly, the univariate association of each of the potential confounders (total added dietary sugar, lollie consumption, mealtime consumption of sugar-containing beverages, tooth brushing frequency, and use of fluoridated toothpaste) with DMFT was assessed. Secondly, the potential confounders that were shown to be significantly associated with differences in DMFT scores were included in a multiple variable regression analysis. As the data were highly skewed (the majority of the children were caries free) a logistic regression model (caries experience was dichotomised as DMFT = 0 or 1+) was developed using the backward stepwise selection option. The analyses were carried out using SAS statistical software, Release 8.2.

Ethics approval for this study was granted by the Human Research Ethics Committee,The University of NIMS.

RESULTS

A total of 404 12-year-olds participated in the study. The children living in the sugarcane belt chewed around three to four sticks of sugarcane daily during the cane harvesting seasons. Since none of the children in either area had received dental care, the DMFT scores reflected decayed or missing teeth only. Caries experience in both areas was confined almost exclusively to the first permanent molars (Table 2). The mean DMFT of the non-sugarcane group was 0.70 (sd=1.17) compared with 0.41 (sd=0.96) in sugarcane group. That is, the mean DMFT score was 71% higher in the non-sugarcane group and further, the proportion of children who had one or more DMFT was 62% higher in the non-sugarcane group. The kappa value relating to diagnostic reliability, based on 51 duplicate examinations, was 0.73. The distribution of mealtime risk factors for caries experience, namely sugar-containing beverages, which are consumed at breakfast, tiffin (lunch), and dinnertime, is shown in Table 3. Except for yoghurt (12% versus 3.9%), the consumption of all other sugar-containing beverages at breakfast was greater in the sugarcane group than in the non-sugarcane group ($p<0.001$). At tiffin (lunch), more milk with added-sugar was

Table 2: Caries experience by residential location

	Mean		DMFT = 0		DMFT = 1+			
	n	DMFT	(sd)	n	%	n	%	p-value*
Non-sugarcane	200	0.70	1.17	127	63.5	73	36.5	0.002
Sugarcane	204	0.41	0.96	158	77.5	46	22.5	

*Chi-square = 9.45, DF = 1

Table 3: Mealtime intake of water and sugar-containing beverages

		Water		Milk		Tea		Yoghurt			
Meal	Residential location	n	%	n	%	n	%	n	%	Total	p-value*
Breakfast	Non-sugarcane	84	42.0	5	2.5	87	43.5	24	12.0	200	<0.001
	Sugarcane	78	38.2	22	10.8	96	47.1	8	3.9	204	
Tiffin	Non-sugarcane	21	10.5	86	43.0	86	43.0	7	3.5	200	<0.001
	Sugarcane	56	27.5	39	19.1	102	50.0	7	3.4	204	
Dinner	Non-sugarcane	32	16.0	32	16.0	112	56.0	24	12.0	200	<0.001
	Sugarcane	56	27.5	25	12.3	56	27.5	67	32.8	204	

consumed by the non-sugarcane group (43% versus 19%) and at dinnertime, more sweetened tea was consumed by the non-sugarcane group (56% versus 27.5%) ($p<0.001$).

Table 4 shows the distribution of exposure to additional caries risk factors, namely tooth brushing habits, lollie consumption, and total daily added-sugar to children in both residential locations. Both groups had almost identical tooth brushing habits regarding brushing frequency and use of fluoride toothpaste. One quarter of the children reported that they brushed daily and 60% reported that they used fluoridated toothpaste. More children in the non-sugarcane group (88% versus 70%) consumed 4 or more lollies per day than in the sugarcane group ($p<0.001$). An almost identical amount of total daily added-sugar was consumed by both groups; the median amount was 8 teaspoons per day. This amount included sugar that is eaten by itself, as a sweet, directly after a meal. The mean DMFT scores were lower in sugarcane group in relation to each of the risk/protective factors.

In the multivariable logistic regression analysis of risk factors for a caries experience (Table 5), all but one of the factors were dropped from the model, leaving residential location area alone as the sole significant predictor of experiencing one or more DMFT. Compared with children in the non-cane region, the children residing in the sugarcane growing region were 49% less likely to have decayed teeth (OR=0.51; 95%CI= 0.33, 0.78)

DISCUSSION

Although overall caries experience of children in both regions was low, a clear cut association between exposure to raw sugarcane and caries experience was evident. The important question is: whether or not this association is causal. In this parallel cross-sectional study, the caries experience outcome was measured directly on the day of the survey, while exposures to the risk factors of interest were inferred on the basis of the current habits of the children. The weakness of this research design is the assumption that measures of exposure, based on current habits, may be biased estimates of previous habits. Hence, the inference we have drawn on the basis of the exposure estimate can only be interpreted as suggestive of a causal link, rather than proof of one. To prove causation, the ideal research design would be that of a controlled cohort study in which children would be followed for a period, throughout which their exposure to sugarcane and relevant confounding factors, would be assessed at regular intervals. In this way, the exposures could be better quantified.

The explanation of the effect of sugarcane on caries incidence is problematic. Both organic and inorganic phosphates have been investigated in this regard. A review of more than 100 experiments showed conclusively that the addition of inorganic phosphates to cariogenic diets reduced the caries experience in animals (23). However, in a human clinical trial in which sweets supplemented with dicalcium phosphate were provided to school children over a three year period, no reduction in caries incidence was observed (24). The potential anti-cariogenic effect of the organic phosphate, calcium sucrose phosphate, already referred to, is to raise both calcium and

Table 4: Exposure of the children to protective/risk factors for dental caries and their caries experience byresidence location

		Sugarcane		Non-sugarcane			Mean DMFT (SD)				
Risk/protective factor	Exposure	n	%	n	%	p value	Sugarcane		Non-sugarcan		p value
Toothbrushing frequency	Daily	54	26.5	53	26.5	0.916	0.48	(1.04)	0.77	(1.14)	0.168
	Weekly	150	73.5	147	73.5		0.39	(0.93)	0.67	(1.19)	0.021
Toothpaste use	Fluoride	116	56.5	119	59.5	0.590	0.45	(1.04)	0.53	(0.84)	0.601
	Non-fluoride	88	43.1	81	40.5		0.38	(0.91)	0.82	(1.35)	0.004
Lollies	2 per day	64	30.0	23	12.0	<0.001	0.39	(0.95)	0.65	(1.15)	0.280
	4 per day	140	70.0	177	88.0		0.42	(0.97)	0.71	(1.18)	0.021
Total daily added sugar	0 - 4	21	10.3	12	6.00	0.383	0.28	(0.64)	0.58	(0.80)	0.249
(number of teaspoons)	5 - 6	42	20.6	45	22.5		0.55	(0.83)	0.57	(1.03)	0.881
	7 - 8	79	38.7	74	37.0		0.38	(1.04)	0.73	(1.39)	0.078
	9+	62	30.4	69	34.5		0.40	(1.03)	0.77	(1.07)	0.049

Table 5: Odds ratio from best fitting multiple variable logistic regression model (using the backward stepwise selection method) of risk factors* for dental caries experience**

Explanatory variable	Variable category	Odds ratio	95% CI	p value
Residential area	Sugarcane area	0.507	0.327, 0.784	0.0023
	Non-sugarcane area (reference category)			

* The effects of sugar consumption at breakfast, tiffin (lunch) and dinner, and the effect of lollie consumption were dismissed ($p > 0.05$) during successive steps.
** Dichotomised as DMFT = 0 or 1+

phosphate levels in plaque and saliva and its anti-cariogenic effectiveness is reportedly due to its ability to adsorb firmly to enamel surfaces and thus prevent its dissolution. In this regard, phytate, derived from unrefined cereals was identified as being more active than calcium sucrose phosphate (25). Wilson and Ashley (26) have reported on studies that have shown a strong relationship between levels of calcium and phosphate in plaque and caries incidence in adolescents. The increased concentration of calcium and phosphate in saliva reduces the likelihood of enamel dissolution as pH falls (27). However, more recently, in a 2-year cohort study of children aged 12 years, Pearce et al. (28) demonstrated that while plaque calcium and phosphate were highly correlated with each other, when a set of confounding variables were taken into account, only calcium, and not phosphate, was significantly associated with a caries incidence of three or more DMFS.

On the other hand, the Indian diet is rich in milk, yoghurt, and cheese. In 1975, Rugg-Gunn reported that eating cheese after a sugar-containing snack returns plaque pH to a safe level within 5 minutes (29). It has been proposed that this effect could be due to the stimulation of salivary flow which causes pH rise, or to the raising of calcium concentrations in plaque, or to increasing alkaline substances in plaque, or finally, due to the adsorption of a protective protein, such as casein (a phosphorprotein), on the enamel surface, thereby physically slowing the dental caries process (29, 30). In a more recent review of the anti-cariogenicity of dairy products, it was reported that in rat caries models, caries incidence is reduced significantly by the addition of soluble caseinate to drinking water or confectionery (31). Although not measured directly in this study, it is assumed that exposure to dairy products was the same in both areas.

In summary, the lower caries experience observed in the sugarcane group may be due to the protective effect of an organic phosphate, such as calcium sucrose phosphate, however, as already noted, the chewing of sugarcane stimulates saliva production, the rinsing effect of which reduces the potential for the sucrose to depress pH. Alternatively, the chewing effect itself, on saliva stimulation, may be the protective factor, since the pH fall associated with chewing on sucrose-sweetened gum is neither deep nor long lasting as compared with the fall which follows a sucrose exposure alone (32). A low caries experience was observed in both groups of children, despite their very high consumption of added sugar; sugar which is added, two spoonfuls at a time, to beverages including milk and yoghurt. In addition, for good measure, a spoonful of sugar is eaten by itself frequently, at the end of a meal. In other environments, this is a recipe for high caries experience. These observations indicate that our understanding of the relationship between caries and refined carbohydrates remains rudimentary.

CONCLUSION

It is concluded that the lower caries experience of Punjabi children, who chew large quantities of sugarcane daily during a period of about six months per year, is supportive of the hypothesis that raw sugarcane is associated with a caries protective effect. The protective factor may be intrinsic to the sugarcane such as an organic phosphate, or extrinsic, such as a saliva factor that is associated with vigorous chewing.

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