Dietary patterns, toothbrushing habits and caries experience of schoolchildren in West Yorkshire, England.

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Objective and method: The present study followed a group of 608 children, aged 7-11 years from six primary schools, for whom detailed dietary information was available. These children were traced four years later when they were in secondary school. The aim of the study was to investigate the relationship between the original dietary pattern, current dietary pattern, toothbrushing habit and oral health. Of the original children, 500 were traced to 32 secondary schools over a wide geographic area. For logistical reasons those in 18 schools were selected and positive consent and full data was obtained for 315 together with an additional group of 122 of their classmates. Three-day, self-reported dietary data was obtained, together with information on toothbrushing habits. A dental examination was carried out using BASCD survey methodology. ***Results***: The children in this study had a lower DMFT (0.82) than found in the most recent survey for the area (1.39). No significant relationship was found between sugar-sweetened foods or drinks at age 7-11 and caries in the first permanent molar teeth at age 11-15 years, however a significant relationship was found between current sugar-sweetened drinks consumption and caries. Significantly less caries was associated with the reported moderate consumption of dairy products by the children when aged 11-15 years. The bedtime consumption of NMES drinks at 7-11 was significantly associated with an increase in caries as was the bedtime consumption of non-milk extrinsic sugars (NMES) foods at 11-15 years. A significant inverse relationship was found between claimed toothbrushing frequency and caries. Of those children aged 11-15 years claiming to brush at least once a day, 69% were caries-free with a mean DMFT of 0.69. Of the children who claimed to brush only occasionally or never, 52% were caries-free and they had a mean DMFT of 1.05. ***Conclusion***: The reported consumption of sugar-sweetened drinks and the lack of regular toothbrushing were found to be the factors most strongly linked to caries and this finding is consistent with other recent studies.

Key words: Dental caries, diet, toothbrushing.

Introduction

There is abundant evidence that dietary patterns in children have an influence on caries experience (Moynihan, 2003). While much of this evidence is from cross-sectional studies, it is recognised that caries takes time to develop and the caries status of an individual may reflect the dietary pattern at an earlier age. The lack of a substantial body of published studies relating early dietary patterns with the subsequent development of caries reflects the difficulty in conducting such longitudinal studies.

Following the introduction of fluoride toothpaste it has been recognised that daily brushing with fluoride toothpaste is an effective means for personal caries prevention (Nyvad, 2003). The widespread use of topical fluoride agents, both professionally and self-applied in the form of toothpaste and rinses, together with ingested fluoride from the water supply and supplements now make it more difficult to determine which is the more important means of caries prevention, dietary control or brushing with fluoride toothpaste.

Between 1996 and 1998, an interventional study, the APPLES project, was conducted in ten Leeds, West Yorkshire primary schools aimed at documenting the dietary and physical recreation patterns of 7-11 year old children, followed by dietary advice using nationally agreed guidelines (Sahota *et al*., 2001). While a follow-up study showed that the intervention had only a modest influence, the value of the study was to provide a detailed indication of dietary pattern in this age group. The existence of detailed dietary information on this cohort of primary school children provided the opportunity to follow the original subjects and to study the relationship between diet and the development of dental disease. The aim of this study was to investigate the relationship between the original dietary pattern in 1996 – 98 and the current dietary pattern, toothbrushing habits and oral health of the APPLES children in 2001 when the children were in secondary school and aged 11-15 years. The dental study formed one part of a larger investigation to follow the development of the original subjects and to study the relationship between diet, physical activity and physical development, specifically regarding childhood obesity (Rudolf *et al*., 2004).

Method

The original APPLES study was conducted in ten primary schools in the Leeds area. The schools were selected to provide a range of socio-economic status and data was collected on children in school years 3 to 6 annually from 1996 to 1998. Dietary data was collected on three occa-

sions by 24-hour recall and also using three-day diaries completed by the children with the assistance of the class teacher. These data included the intake of calcium rich foods, and the portions and frequency of sugary foods and drinks through the day. The original sample consisted of almost all children in these year groups, as only 21 children had not consented to participate. In total, 674 children (358 boys and 316 girls) were included in the school registers and full data sets were obtained for 608 children. Since this study was concerned with children's diet and physical activity, no dental examination was performed nor was any information obtained about oral hygiene practices.

At the time of the present APPLES 2 study, the children had moved to secondary schools. In order to trace these children, leaving lists were obtained from the ten primary schools that had taken part, along with the child's destined secondary school. The database of the Leeds Education Authority was accessed for any missing information. Eighty two of the original APPLES children could not be traced. This loss was partly due to the considerable difficulty encountered in tracing children who had migrated over a large geographic area and also to apparent changes of surname and dates of birth. However 526 were traced, but were found to be scattered across 32 schools within West and North Yorkshire, covering a geographical area over 30 miles wide. Such a spread of children across so many secondary schools had not been anticipated at the planning stage as most of the primary schools were sited on the north side of Leeds. For logistical reasons it was decided to restrict the study to 500 children in the 18 schools that had more than six of the original subjects. All of the original APPLES primary schools and the secondary schools in the follow-up study were in areas with water supplies containing less than 0.3 ppm fluoride.

Ethics approval for the study was obtained from the United Leeds Teaching Hospitals Ethics Committee. Head-teachers and Governors at the selected schools gave their approval and were consulted on the format and content of information provided to the subjects and parents or carers who were asked to give positive informed consent.

Dietary data

The 24-hour dietary recall protocol developed for the original project was adapted for use in this study. This was based on a checklist in which all possible foods for each of the meals eaten during the day were listed with an option to record food consumed not on the list. The questionnaire was refined so that only coded information was obtained. On receiving consent to participate, pupils were given two sets of questionnaires to complete prior to the survey visit, one on a weekday and one on a Saturday or Sunday. The third was to be completed on the day of the survey at school. As in the original APPLES study, for each subject the three questionnaires were used to obtain a mean daily intake value for each dietary item. The question on the dietary questionnaire relating to bedtime food and drinks defined bedtime as the hour before bed. In addition, subjects were asked to record their toothbrushing frequency. Because of the

difficulty in obtaining all three sets of questionnaires for each child, it was decided not to attempt to obtain a replicate sample for a reproducibility analysis.

Dental examination

The subjects were examined using the standard method developed for the BASCD UK National Dental Health Surveys, by an observer (RSL) trained and calibrated to BASCD survey standards. Using only a mirror and simple halogen light, the children were examined lying horizontally, the teeth being dried with cotton wool rolls as needed. Radiographs were not taken. Dental caries was recorded as decayed, missing or filled teeth for both deciduous (dmf) and permanent (DMF) teeth. Caries was defined as the D2 cavitated level. The dental examination was conducted at the same time as a range of general growth measurements and the completion of the final questionnaire, the whole process taking over 40 minutes per child and involved a team of seven researchers. Because of concern over disruption to teaching at a busy time in the school calendar, no attempt was made to obtain a replicate sample for a reproducibility analysis.

Statistics

DMFT at increasing levels of food and drink consumption were analysed using the linear component of the medians test. Percent DMFT>0 was analysed for the same break-downs using the linear chi-square analysis (Tables 1, 2).

DMFT at different levels of consumption of dairy products was compared using the Kruskal Wallis Test for DMFT and chi square with two degrees of freedom for % DMFT > 0. Percent DMFT>0 was analysed for the same break-downs using the continuity chi-square with two degrees of freedom (Tables 3). DMFT under different tooth brushing regimens was compared using the Mann-Whitney U test. Percent DMFT>0 was compared for the two groups with a chi square with 1 degree of freedom and Yates's correction. Multivariate and logistic regression analyses were also performed, Table 5.

The original APPLES children when examined in 2001 ranged in age between 11.5 and 15.3. Age correction was not used for the analyses. There were statistically insignificant differences in age between males (13.4) and females (13.3) (t test probability=0.074), or between daily and less frequent brushers (respectively 13.37, 13.39, t test probability=0.80). There is a very small difference in ages between those with and without decayed, missing or filled teeth (respectively 13.3, 13.5, t test probability=0.015).

While full data was obtained for only 52% of the original APPLES children no significant difference was found in the original dietary pattern between those who were seen at follow-up and those who were not.

Results

Of the 500 original APPLES subjects who were traced to 18 secondary schools positive consent was obtained for 338 and complete dietary data and dental examinations were obtained for 315 subjects. During the APPLES 2 study, the opportunity arose to obtain data for an ad-

Table 1. Caries and reported daily NMES consumption frequency

		Consumption frequency / day				
		<2	2-3	4+	All	p
NMES Food						
Consumption at 7-11	n	31	130	152	313	
	DMFT	1.00	0.7	1.09	0.92	0.23
	%DMFT>0	39	35	43	39.3	0.26
Consumption at 11-15	n	253	133	51	437	
	DMFT	0.79	0.84	0.88	0.82	0.41
	%DMFT>0	36	39	39	37.1	0.48
NMES Drinks						
Consumption at 7-11	n	74	171	67	312	
	DMFT	0.81	0.92	1.03	0.92	0.92
	%DMFT>0	43	37	42	39.4	0.83
Consumption at 11-15	n	215	169	53	437	
	DMFT	0.78	0.79	1.08	0.82	0.047
	%DMFT>0	35	35	53	37.1	0.061

Probability (*p*) is based on the linear component of the medians test for DMFT and the linear component of chi square for % DMFT > 0.

Table 2. Caries and reported daily bedtime NMES consumption frequency

		Consumption frequency / day			
		<1	+1	All	p
NMES Food					
Consumption at 7-11	n	195	120	315	
	DMFT	0.87	1.00	0.92	0.938
	%DMFT>0	39	40	39.7	1
Consumption at 11-15	n	355	82	437	
	DMFT	0.78	1.00	0.82	0.037
	%DMFT>0	35	46	37.1	0.072
NMES Drinks					
Consumption at 7-11	n	238	77	315	
	DMFT	0.82	1.25	0.92	0.031
	%DMFT>0	37	49	39.7	0.063
Consumption at 11-15	n	383	54	437	
	DMFT	0.83	0.74	0.82	0.64
	%DMFT>0	36	43	37.1	0.46

Probability (*p*) is based on the Mann-Whitney U test for DMFT and chi squared test with Yates's correction on 1 degree of freedom and for % DMFT > 0.

Table 3. Caries and reported daily dairy product consumption frequency

		Consumption frequency / day				
		<2	*2-3*	*4+*	*All*	*p*
Consumption at 7-11	N	69	10	144	315	
	DMFT	1.32	0.73	0.87	0.92	0.21
	%DMFT>0	46	35	40	39.7	0.35
		<1	*1-2*	*2+*	*All*	*p*
Consumption	N	135	183	119	437	
	DMFT	1.04	0.63	0.86	0.82	0.027
	%DMFT>0	46	32	35	37	0.031

Probability (*p*) is based on the Kruskal Wallis Test for DMFT and chi squared test with two degrees of freedom for % DMFT > 0.
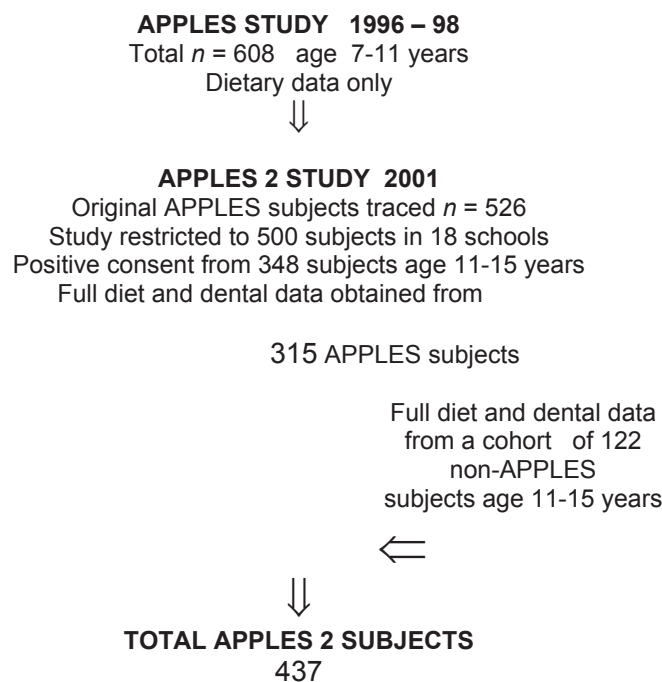
Table 4. DMFT and reported toothbrushing frequency at age 11-15 years

	Toothbrushing frequency			
	At least once daily	*Less than daily*	*All*	*p*
n	285	152	437	
DMFT	0.69	1.05	0.82	<0.001
% DMFT>0	31	48	37.1	0.001

Probability (*p*) is based on the Mann-Whitney U test for DMFT and chi squared test with Yate's correction on 1 degree of freedom for % DMFT > 0

Table 5. Only three predictors were significantly associated with caries. Tooth brushing and moderate dairy consumption at age 11-15 years was advantageous as it was associated with a lower risk of caries (DMFT>0). Bedtime consumption of NEMS drinks at age 7-11 years was a disadvantage as it is associated with higher risk of caries (DMFT>0).

	B	*S.E.*	*Wald*	*Degrees of Freedom*	*Probability*	*Odds Ratio*
Bedtime NEMS Drink First	.654	.307	4.548	1	.033	1.923
Dairy Products Second	-.495	.252	3.861	1	.049	.610
BRUSHING	-.647	.252	6.581	1	.010	.524

APPLES STUDY   1996 – 98
Total *n* = 608   age 7-11 years
Dietary data only
⇓

APPLES 2 STUDY 2001
Original APPLES subjects traced *n* = 526
Study restricted to 500 subjects in 18 schools
Positive consent from 348 subjects age 11-15 years
Full diet and dental data obtained from

315 APPLES subjects

Full diet and dental data
from a cohort   of 122
non-APPLES
subjects age 11-15 years

⇐

⇓
TOTAL APPLES 2 SUBJECTS
437

Figure 1. *Flow diagram illustrating composition of subjects in data sets.*

ditional group of 122 11-15 year old children in one of the schools who were not part of the original study but were now in the same school year. While initial data was not available for this group, they were included in the analysis of the APPLES 2 data relating current diet and toothbrushing habits to current oral health to form a separate data set. The composition of these groups is shown in Fig 1.

Since very few deciduous teeth were present at the dental examination only the results for the permanent dentition are reported.

Diet & caries

All dietary items containing non-milk extrinsic sugars (NMES) as defined by, the COMA Report (Department of Health, 1989) were included in the NMES dietary group.

For the total consumption of NMES, caries experience tended to increase with the reported consumption of both NMES foods and drinks as reported at 7-11 year and 11-15 years, but the trend was only statistically significant for consumption of NMES drinks at age 11-15 with DMFT (mean difference = 0.30 DMFT, 95% ci –0.01 -+0.70), (Table 1).

For the consumption of NMES in the hour before bedtime, caries experience also increased with higher reported consumption of both NMES drinks and food, but the association was only statistically significant for the association between DMFT and the reported bedtime consumption of NMES food at age 11-15 (mean difference = 0.22 DMFT, 95% CI –0.10 - +0.55) and drinks at 7-11 (mean difference = 0.43 DMFT, 95% CI -0.04 - +0.90), (Table 2).

A moderate consumption of dairy products at both ages was associated with less caries, but this association was only for a frequency of less than three times daily as reported at 7-11 years and less than twice daily at 11-15 years (Table 3). This association was only statistically significant for consumption of less than two dairy items per day at age 11-15 years. Higher and lower intake frequencies at both ages tended to be associated with greater caries experience.

Toothbrushing frequency and caries

The data for toothbrushing and caries relates to the information provided by the subjects when aged 11-15 years as these data were not obtained during the initial study.

A highly significant relationship was found between claimed toothbrushing frequency and caries. Of those children aged 11-15 years claiming to brush at least once a day, 69% were caries-free with a mean DMFT of 0.69. Of the children who claimed to brush only occasionally or never, 52% were caries-free and they had a mean DMFT of 1.05, an increase of nearly 50% over the regular brushers (Mann-Whitney *P*<0.001), (mean difference = 0.36 DMFT, 95% CI +0.07 - +0.65), (Table 4). No gender difference was found.

A multivariate analysis was performed to test the influence of potential confounding factors. No significant relationships were found between gender, age and dietary patterns or toothbrushing frequency. In the logistic regres-

sion, only moderate intake of dairy products and daily toothbrushing were predictive of caries-free status while bedtime NMES drinks were predictive of the presence of caries (Table 5)

Discussion

This was an opportunistic study, taking advantage of the availability of dietary information from what was originally a single phase study to follow up the original subjects. While the dietary data from the original 315 APPLES subjects in 1996-98 has been related to their dental state in 2001, the diet and toothbrushing data obtained in the APPLES 2 study, which includes the additional group of 122 non-APPLES subjects forms an independent data set of 437 subjects, which has been related to the dental health of the whole subject group.

Because of the nature of this study, there are a number of confounding factors. The first is the possible bias due to the loss of subjects between the original APPLES study and APPLES 2. Because of the sensitivity of some adolescent children to body shape, there was concern that some overweight or obese children would not participate. However a comparison of the original diet, height, weight and body mass index of the APPLES children participating in the follow-up and those not doing so showed no significant differences. The second confounding factor is the lower than expected caries level in the subjects, both the original APPLES children and the additional group of 122 subjects. This may be due to the effect of the need for positive informed consent for a complex and demanding assessment, including detailed growth and bone density measurements, producing a better response rate from the higher socio-economic group families.

An important consideration in the interpretation of these data is that the dietary pattern of young children can change rapidly. The ages of the children when seen initially in primary school ranged from 7 to 11 years. When again seen in secondary school the ages ranged from 11 for those who had been seen when aged 7 in primary school to 15 years for those seen just before leaving primary school at 11 years of age. Hence the age range at both observation points is contiguous. At each observation, the 4-year age span of the children must include a wide variation in dietary patterns, but because of the relatively small numbers involved it was not practical to analyse the data by age. This must be accepted as a confounding factor.

The findings generally support existing evidence on the relationship between caries and diet. The failure to show a strong relationship between the consumption of NMES foods by the children when aged 7-11 and the development of caries at age 11-15 years could be related to the change in the diet during this period. A further factor is that during the initial study the children would have only had four posterior permanent teeth, the others erupting by 11-15 years. It must also be recognised that self-reporting is not a robust research tool and the dietary diaries in young children in the initial study were completed by the children with the assistance of classroom teachers and teaching assistants. However the most important factor in this respect is the very low

caries prevalence in the sample, 276 (63%) being caries free. Overall, in this study the children had a lower mean caries prevalence (DMFT = 0.82) than that found in the most recent survey of Leeds 12 year-olds (DMFT = 1.39) (Pitts *et al*, 2000). The finding of a significant relationship between caries and the initial bedtime consumption of NMES drinks is consistent with previous studies (Levine 2001). However this relation was not seen when compared to current bedtime consumption at 11-15 years, providing support for the concept that the dietary environment into which teeth erupt is an important factor in determining caries experience.

The consumption of dairy products is recognised as a protective dietary factor (Rugg-Gunn & Nunn, 1999) and the finding of a reduction in DMFT with moderate consumption, significant at 11-15 years, is consistent with previous studies. The trend for caries to increase from the lower figures with higher consumption of dairy products at both 7-11 years and at 11-15 years is puzzling, but might suggest an increased intake of sugar-sweetened dairy products such as milkshakes. Overall, the children who were followed had a lower frequency of consumption of both NMES containing items and dairy products in secondary school when aged 11-15 years, compared to their consumption in primary school.

In assessing the results from the tooth brushing data, we have assumed that the vast majority of the children would be using a fluoride containing toothpaste. The finding of a significant difference in caries prevalence between those children who did not brush regularly and those who brushed at least once a day is strong support for the effectiveness of the regular use of fluoride toothpaste for caries prevention. Indeed, the finding that children who did not brush regularly had almost 50% more caries than regular brushers is higher than the benefits suggested from most fluoride toothpaste trials comparing fluoride toothpastes with placebo toothpastes (Ellwood & Fejerskov, 2003). This finding is consistent with the view expressed by some authorities of an additional benefit from the mechanical removal plaque beyond that attributable to the fluoride content of the paste.

The findings from this study support previous research on the relationship between caries, diet and tooth brushing from the UK National Diet and Nutrition Survey (Walker et al., 2000). The results suggest that the consumption of sugar-sweetened drinks is possibly a more important determinant for caries than the consumption of sugar-sweetened foods and would support the advice that water should be the main fluid intake for children (Levine & Stillman-Lowe, 2004). The finding of a significant relationship between the consumption of sugar-sweetened drinks at bedtime and caries further supports previous research and is consistent with the advice that the hour before bed should be a "*sugar-free zone*". Despite the low overall caries prevalence in this study, the finding that the lack of regular tooth brushing was associated with a 50% increase in caries is consistent with the established advice to brush twice daily with the fluoride toothpaste (Levine & Stillman-Lowe, 2004).

References

Department of Health. (1989): *Dietary sugars and human disease.* Report of the Committee on Medical Aspects of Food Policy [COMA]. London: HMSO.

Ellwood R & Fejerskov O (2003): The clinical use of fluorides, In; *Dental Caries*; eds. Ole Fejerskov & Edwina Kidd. pp189-222. Oxford: Blackwell Munksgaard.

Levine RS (2001): Caries experience and bedtime consumption of sugar-sweetened foods and drinks - a survey of 600 children. *Community Dent Health*, **18**:228-231.

Levine RS & Stillman-Lowe CR. (2004): *The Scientific Basis of Oral health Education* London: BDJ Books.

Moynihan P J. Diet and dental caries (2003): *In The Prevention of Oral Disease* 4th edn; eds. Murray J J Nunn J H and Steele J G., pp. 10-34. Oxford: Oxford Medical Publications.

Nyvad, B. (2003): The role of oral hygiene, In; *Dental Caries*; eds. Ole Fejerskov & Edwina Kidd. pp189-222. Oxford: Blackwell Munksgaard.

Pitts N.B, Evans, D.J, & Nugent, Z.J. (2000) The dental caries experience of 14-year-old children in the United Kingdom. Surveys coordinated by the British Association for the Study of Community Dentistry in 1998/99. *Community Dent Heath* **17**:48-53.

Rugg-Gunn, AJ & Nunn, JH (1999): *Nutrition, Diet and Oral Health*. pp 25-58. Oxford: Oxford University Press.

Rudolf MCJ, Greenwood DC Cole TJ, Levine RS Sahota P, Barth JH, Walker J. Holland PC Cade jand Truscott J (2004): Rising obesity and expanding waistlines in school children: a cohort study. *Arch Dis Child*. **89**, 235-237.

Sahota P, Rudolf MCJ, Dixey R, Hill AJ, Barth JH, Cade J (2001): APPLES: Process and impact evaluation of a primary school based obesity prevention programme in the UK. *Br Med J* **323**, 1029-10

Walker A, Gregory J, Bradnock G, Nunn, J, White D. (2000): National Diet and Nutrition Survey: young people aged 4 to 18 years. Volume 2: Report of the Oral Health Survey. London: TSO.