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Long term evaluation of the clinical effectiveness of community milk fluoridation in Bulgaria

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Objective: To determine the clinical effectiveness of a community milk fluoridation programme. ***Basic research design:*** Parallel arm 5-year cohort study, with final cross-sectional comparisons between groups. ***Participants:*** 3-year-olds in 8 Bulgarian cities/towns entered the cohort study with random samples (n=1,782) recruited at baseline in 2004. After 5 years in 2009 sub-samples (about 30%) of these now aged 8 were randomly selected in intervention sites for follow-up examination (n=454); 276 controls were examined at the age 8 years. For cross-sectional comparisons, in 2004, 284 3-year-olds from control cities were baseline examined for caries, then 276 children at the age 8 years in 2009. ***Interventions:*** In six intervention communities: 1,498 examined children received 0.5mg F in 100 or 200ml school milk or yogurt provided each school day; a further 180 received non-fluoridated milk. In two control communities, fluoride was not added to 284 children's school milk. ***Main outcome measures:*** Dental caries experience of primary, and permanent teeth. ***Results:*** For primary teeth, caries increments were 46% ($p<0.001$) and 30% ($p<0.01$) lower in the fluoridated milk groups compared with non-fluoridated milk groups in the intervention and control communities, respectively. For permanent teeth those reductions were 61% and 53% ($p<0.001$). The cross-sectional comparisons of 8-year-olds showed significant changes in dental caries experience over time; in children consuming fluoridated milk the level of dmfs fell by 43% (2004 and 2009) against 11% in the control group. Among children consuming fluoridated milk the DMFS fell 68% against rising 3% in the controls. ***Conclusions:*** Fluoridated milk delivered daily in schools in Bulgaria resulted in substantially lower caries development compared with children in schools receiving milk without added fluoride. The nation-wide experiences from milk fluoridation indicate that such a public health scheme can be effective to the global fight against dental caries of children.

Key words: *dental caries prevention; fluoridated milk; cohort study; children; Bulgaria*

Introduction

The prevalence of non-communicable diseases is significant worldwide; they represent a comprehensive burden to people and society, display large disparities across countries, disproportionately affect poor and disadvantaged population groups, and they are increasing rapidly across the globe (WHO, 2011). Oral diseases are among the most prevalent non-communicable diseases and show disparities comparable to other chronic diseases (Petersen, 2005; Petersen *et al.,* 2005). Their treatment is most expensive for individuals and society (Petersen, 2008) with dental treatment, mostly related to dental caries, in the EU costing an estimated €79 billion in 2011 (Patel, 2012). Within Europe there is considerable variation in dental caries experience, with much of the burden now in the emerging economies of eastern and south-eastern Europe (WHO, 2013). Eastern European countries have not yet attained the WHO regional targets for child oral health by the year 2000, i.e. at least 50% of 6-year-olds should be free of dental caries and on average no more than 2 DMFT for 12-year-olds. Thus, effective implementation of preventive programmes is urgently needed in particular for these countries to achieve the oral health targets for 2020 (WHO, 1999), i.e. at least 80% of 6-year-olds being caries free and on average no more than 1.5 DMFT for 12-year-olds. Many of these countries are currently undergoing nutrition transition and do not have adequate fluoride exposure (Moynihan and Petersen, 2004; Petersen and Lennon, 2004; WHO, 2003;WHO, 2015). With the limited access to oral health services, professionally applied fluoride regimes may prove inadequate for dental caries prevention and control, and automatic fluoridation (e.g. water, salt or milk) in addition to use of fluoridated toothpaste may be the most viable solution for effective disease prevention (Jones *et al*., 2005; Petersen, 2008; WHO, 1994). Milk fluoridation, as an alternative to water fluoridation, is one of the operative strategies in population-directed caries prevention (Bánóczy *et al.,* 2009). Milk fluoridation as part of general health promotion programmes can promote healthy diet and nutrition and can also be integrated effectively into health-promoting school initiatives. Fluoridating school milk costs about €2-3 per child per year (Bánóczy *et al*., 2013).

The dental health of Bulgarian children was poor in the 1980s, with high levels of untreated caries (WHO, 2014). To address this public health problem, the first milk fluoridation scheme was introduced in 1988 in the town of Asenovgrad; this was the first field demonstration study to determine if milk fluoridation may be effective in caries prevention in children under 'real-life' conditions.

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Children aged 3-10 years received 200 ml of milk or milk products containing 1mg of fluoride (5ppm F as NaF) in municipal kindergartens and primary schools during the study period. Random samples of children were selected for clinical dental examination at baseline in 1988 and at follow-up evaluations in 1991 and 1993. Compared with the controls who did not receive fluoridated milk, a reduction of approximately 40% in dental caries in the primary dentition and 79% in the permanent dentition was observed after 5 years (Pakhomov *et al*., 1995) with similar benefits in older children (Atanassov *et al.,* 1999).

Following these results, the Bulgarian Ministry of Health expanded the scheme nationwide, as part of broader health promotion initiatives in kindergartens and schools, to those cities in need of caries prevention programmes and whose local authorities accepted the administration of a milk fluoridation programme. By 2003/4, over 30,000 kindergarten children received fluoridated milk and/or yogurt in seven cities (Table 1). In the early 2000s, it was thought desirable to re-evaluate the programme. Thus, the aim of this study was to evaluate the oral health outcome of this expanded national milk fluoridation programme from 2004 to 2009 in Bulgaria. The specific objectives were to measure the increment of dental caries (dmfs/DMFS) among children enrolled in milk fluoridation programmes relative to children exposed to non-fluoridated milk, and to measure the trend in background dental caries experience over 5 years.

Method

The design of the evaluation was a cohort study with parallel control, supplemented with repeat cross-sectional examinations to determine change in background caries experience. Examiners evaluating the effect were not blind to group identity. Children in all seven cities where milk fluoridation was provided were to be included in the evaluation (Table 1). There were also children in the intervention cities who received non-fluoridated milk. Two cities, Pleven and Sliven, served as control communities where children received milk/yogurt with no fluoride added. These communities were matched with the intervention communities using the United Nations Development Programme (UNDP) Human Development Index (UNDP, 2002). The total population of these nine cities varied between 150,000 and 250,000. The evaluation protocol was approved by the relevant research ethics committees. Dental examinations of 3-year-olds of both genders as the milk fluoridation programme began and five years later, 8-year-olds allowed evaluation of the intervention. Multi-stage cluster sampling procedures were employed in both test and control sites. Random samples of 3- and 8-year-olds were recruited at baseline in 2004 and in 2009 for cross-sectional comparisons. Based on a power calculation, sub-samples (about 30%) of children were randomly selected from the 2004 sample groups for follow-up evaluations (WHO, 1997). Written informed consent was sought from the parents of children sampled. Clinical examinations conformed to WHO standards and criteria (WHO, 1997). Caries experience is expressed as the number of decayed, missing or filled tooth surfaces per child. Nine local clinical examiners, one from each of the participating sites, were trained and calibrated by an international epidemiologist (PEP) in 2004 and in 2009. Good inter-examiner reproducibility was achieved, with a mean Kappa score of 0.82, range 0.74 to 0.85. Intra-examiner variability assessments were conducted regularly by the nine examiners themselves (K range 0.71 to 0.93).

Data were analysed by use of frequency distributions and by calculation of means of caries indices (dmfs and DMFS). Analysis of variance (ANOVA) was used in statistical evaluation of means while the Chi-square test was applied for evaluation of differences in proportions. Alpha level was set at 0.05.

Results

The rate of parental consent and participation in the evaluation was 94%; 91% in the intervention communities and 97% in the control communities. In 2004, 1,782 3-year-olds and 1,041 8-year-olds were clinically examined. In 2009, 442 3-year-olds in the intervention sites and 100 from the control cities were examined (Table 2). In 2009 the 8-year-olds examined were: 454 intervention community children previously examined in 2004 and in the fluoridated milk group for five years; a random sample of 180 children from the same communities neither examined in 2004 nor part of the milk fluoridation programme, and 96 children from the control community. Examination of children was not possible in Dobrich in 2009.

Table 1. Bulgarian cities and the number of children (n_{total}=31,540) who received fluoridated milk or milk products in school in 2003, together with types of milk products, fluoride concentrations and dosage

Cities	Number of children	Type of milk products	F-concentration, ppm	F-dosage, mg/day	Volume per child per day, ml
Bourgas	5,500	Milk and yogurt	2.5	0.5	200
Dobrich	2,390	Milk and yogurt	2.5	0.5	200
Plovdiv	8,690	Milk	5	0.5	100
Shoumen	2,100	Milk and yogurt	2.5	0.5	200
Stara Zagora	2,400	Milk	5	0.5	100
Varna	8,900	Milk and yogurt	2.5	0.5	200
Veliko Tärnovo	1,560	Milk and yogurt	2.5	0.5	200

Considering time trends in caries experience for children in the control community, there was little change in caries experience in both primary and permanent dentitions in the control communities, though the caries experience of 3-year-olds in the intervention communities had fallen by 33%, over the 5 years (Table 3). In 2004, there was little difference in dmfs between children living in the intervention and control communities (p>0.05).

Turning to caries increments, children receiving fluoridated milk had 5 year caries increments of 4.20 dmfs and 0.48 DMFS compared to those in the control communities being 7.72 dmfs and 1.24 DMFS, and 5.98 dmfs and 1.02 DMFS for those receiving non-fluoridated milk in the intervention communities (Table 4). Five year caries increments were lower in the intervention community fluoridated milk children by 46% for dmfs and 61% for DMFS when compared with the control group, and by 30% for dmfs and 53% for DMFS when compared with the intervention community children who had received non-fluoridated milk.

Table 2. Number of children clinically examined in 2004 and 2009 in intervention and control communities

	2004		*2009*		
	3 yrs	*8 yrs*	*3 yrs*	*8 yrs(F)*[1]	*8 yrs*[2]
Intervention sites all)	1,498	784	442	454	180
Bourgas	190	130	50	70	30
Plovdiv	396	131	122	94	30
Shoumen	130	131	50	72	30
Stara Zagora	172	130	50	50	30
Veliko Tärnovo	100	131	50	50	30
Varna	510	131	120	118	30
Control cities (all)	284	257	100		96
Pleven	156	129	50		46
Sliven	128	128	50		50
Overall	1,782	1,041	542	454	276

[1] children in the milk fluoridation programme;
[2] children receiving milk without added fluoride; Examination was not possible in Dobrich

Table 3. Time trends in dental caries experience (mean dmfs/DMFS, (sd)) for children who did not consume fluoridated milk during the period 2004 to 2009

Age group	*Communities*		*2004*			*2009*			*Change (2004 to 2009)*	
			dmfs	*(sd)*	*n*	*dmfs*	*(sd)*	*n*		*p*
3-year-olds	Intervention	no F	1.44	(*4.20*)	1,498	0.96	(*3.14*)	442	-0.48 (-33%)	<0.05
	Control	no F	1.72	(*3.95*)	284	1.65	(*3.75*)	100	-0.07 (-4%)	>0.05 ns
			DMFS	*(sd)*	*n*	*DMFS*	*(sd)*	*n*		*p*
8-year-olds	Control	no F	1.20	(*1.74*)	257	1.24	(*1.49*)	96	+0.04 (+3%)	>0.05 ns

Table 4. Dental caries increments 2004 to 2009 (mean dmfs/DMFS (sd)) in cohorts of children in the intervention communities who consumed fluoridated milk (n=454) and those who had not consumed fluoridated milk in both the intervention communities (n=180) and control communities (n=96) together with dental caries increments and fluoride-related reduction in children who had received fluoridated milk compared to those groups who had non-fluoridated milk

Measure	*Community*		*2004 (3yr olds)*	*2009 (8yr olds)*	*5 yr increment*	*Reduction (%)*	*p*
dmfs (sd)	Intervention	F	1.41 (*3.98*)	5.61 (*6.02*)	4.20 (*5.81*)		
	Intervention	no F	1.48 (*3.76*)	7.46 (*7.31*)	5.98 (*6.42*)	1.78 (30%)	<0.01
	Control	no F	1.69 (*3.81*)	9.41 (*8.01*)	7.72 (*9.20*)	3.52 (46%)	<0.001
DMFS (sd)	Intervention	F	0	0.48 (*1.06*)	0.48 (*1.06*)		
	Intervention	no F	0	1.02 (*1.43*)	1.02 (*1.43*)	0.54 (53%)	<0.001
	Control	no F	0	1.24 (*1.49*)	1.24 (*1.49*)	0.76 (61%)	<0.001

Cross-sectional comparisons were made for 8-year-olds (Table 5). For primary teeth, caries experience in those who had received fluoridated milk was 43% lower in 2009 than 8-year-olds in 2004 in the same intervention communities before the milk fluoridation programme started. For children in the intervention communities who had received milk without added fluoride, the decline in caries experience was less at 24%. In the control communities, caries experience fell by 11% during the same period. For permanent teeth, those caries experience differences were 68% lower, 32% lower and a non-significant 3% increase, respectively.

Comparing the dental caries experience between groups recorded in 2009, caries experience was lower in the children who had received fluoridated milk (5.61 dmfs and 0.48 DMFS) than in the control community children (9.41 dmfs and 1.24 DMFS) (p<0.001). Comparisons between the children who had received fluoridated milk and children in the intervention communities who had received milk without added fluoride (7.46 dmfs and 1.02 DMFS) differed as well.

Table 5. Cross-sectional comparisons of dental caries experience (mean dmfs/DMFS, (sd)) of 8-year-olds examined in the intervention (consuming fluoridated milk and consuming non-fluoridated milk) and control communities in 2004 and in 2009 (see Table 2 for numbers of subjects in each group)

Measure	*Community*	*2004*		*2009*		*Change (%)*	*p*	*p for 2009 vs control*
dmfs (sd)	Intervention F	9.88	(8.52)	5.61	(6.02)	-4.27 (-43%)	<0.001	<0.001
	Intervention no F			7.46	(7.31)	-2.42 (-24%)	<0.001	<0.05
	Control no F	10.62	(8.80)	9.41	(8.01)	-1.21 (-11%)	>0.05 ns	
DMFS (sd)	Intervention F	1.51	(2.13)	0.48	(1.06)	-1.03 (-68%)	<0.001	<0.001
	Intervention no F			1.02	(1.46)	-0.49 (-32%)	<0.01	>0.05 ns
	Control no F	1.20	(1.74)	1.24	(1.49)	+0.04 (+ 3%)	>0.05 ns	

Discussion

A recent WHO publication (Bánóczy *et al.,* 2009) summarises the research experience gained from milk fluoridation projects undertaken in various countries. Clinical evaluation studies have been performed in Europe, Asia and the Americas with projects mostly initiated from a public health interest into identifying appropriate strategies for prevention of the unresolved high burden of child dental caries. Different types of evaluative designs have been used ranging from randomized or quasi-randomized controlled trials to cross-sectional designs or time series arrangements. Lessons learnt from the evaluative studies are that children should begin to drink fluoridated milk at an early age, preferably before 4 years, to reduce caries in primary teeth. It would also appear necessary for children to be drinking fluoridated milk when their first permanent molars erupt to protect these teeth. A longitudinal study design with a follow-up period of at least 3 years is recommended for evaluation of public health. These principles were applied in the present study.

The main finding of this evaluation study was that caries increments were substantially lower in the cohort of children who had received fluoridated milk in school for five years compared with two cohorts of children who had received milk in school without fluoride added (Table 4). 2009 cross-sectional comparisons of dental caries experience of 8-year-olds confirmed these findings (Table 5).

Comparative cohort studies are a powerful design but need to be interpreted knowing changes in background (temporal) caries experience in the population (Table 3). There was no change in background caries experience in the control communities for both 3-year-olds (dmfs) and 8-year-olds (DMFS). However, there was a reduction in background caries experience of 3-year-olds in the intervention communities of 33%. The reason for this latter finding is unclear but it could be due to some of the 3-year-olds receiving the intervention before their clinical examination, differences in dietary habits of young children or due to an early exposure to fluoridated toothpaste. The lack of information about fluoride exposure from toothpaste or other sources is a limitation to the study. It has to be recognised that children were not randomly allocated to intervention or control groups as this was an evaluation of a community preventive programme. The examiners were aware whether the community being examined was receiving milk with added fluoride (intervention) or not (control). However, within the intervention communities, the examiners were unaware which children were receiving milk with added fluoride and which without.

These findings are similar to international results of other evaluations of community fluoridated milk programmes (Bánóczy *et al.*, 2009; 2013). In terms of teeth prevented from becoming carious, the primary dentition showed the greatest gain, while in terms of percentage reductions, the permanent dentition showed the greatest gain. Previously published studies had reported reductions in both primary and permanent teeth but this is sensitive to the age children enter the fluoridated milk programme (Bánóczy *et al*., 2009; 2013). In Bulgaria, children entered at age 3 years which allows time for the primary teeth to benefit. In addition, the 5 year study period allowed time for the effect to be evident in permanent teeth of 8-year-olds.

There are now some 19 published evaluations in 12 countries of milk fluoridation, including this study (Bánóczy *et al.*, 2013). Of the 13 studies which have evaluated primary teeth, 11 have reported a reduction and 2 studies reported no reduction. Of the 15 studies which have evaluated permanent teeth, 13 reported a reduction and 2 reported no reduction. Three systematic reviews of milk fluoridation (Australian Government, 2007; Cagetti *et al*., 2013; Yeung *et al.,* 2005) have included a total of six studies out of the above published evaluations – all six reported significant caries reductions.

According to the World Health Assembly Resolutions WHA22.30 (1969), WHA28.64 (1975), WHA31.50 (1978), and WHA60.17 (2007), WHO strongly supports the establishment of automatic fluoridation in countries with low levels of fluoride in drinking-water (Petersen and Lennon, 2005). The most recent statement WHA60.17 (WHO, 2007) encourages member states to confirm prevention of dental caries by systematic use of fluoride through water, salt or milk, and by use of effective fluoridated toothpaste. The statement reads:

(4) for those countries without access to optimal levels of fluoride, and which have not yet established systematic fluoridation programmes, to consider the development and implementation of fluoridation programmes, giving priority to equitable strategies such as the automatic administration of fluoride, for example, in drinking-water, salt or milk, and to the provision of affordable fluoride toothpaste;

Water fluoridation has many advantages as a community preventive strategy; where this is not possible salt fluoridation and milk fluoridation are considered important alternatives (Jones *et al*., 2005; Marthaler and Petersen, 2005). Milk fluoridation is reliant on the existence of a well-functioning school milk programme (Woodward, 2009) while for young children a sustainable infant feeding programme is required (Marino *et al*., 2001).

The burden of dental caries among children in Eastern Europe is expected to persist unless effective disease prevention programmes are established. In principle, preventive programmes may be based on professional efforts oriented towards the patient; meanwhile, population-directed actions are most effective and essential to sustainable health improvement. The incorporation of systematic fluoride schemes - such as milk fluoridation - into national public health programmes is vital to the continuous prevention of dental caries in Eastern Europe. The Health Promoting School provides a unique setting for oral health through fluoride (Jürgensen and Petersen, 2013). The present implementation research demonstrates that milk fluoridation is effective in the global fight against child dental caries.

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References

Atanassov, N., Vrabcheva, M., Todorova, N. and Markova, N. (1999): F-milk scheme for dental caries prevention – 10 years experience. *Modern Stomatology* **2**, 3-5.

Australian Government (2007): *A systematic review of the efficacy and safety of fluoridation.* Canberra: Australian Government, National Health and Medical Research Council.

Bánóczy, J., Petersen, P.E., and Rugg-Gunn, A.J. (2009): *Milk fluoridation for the prevention of dental caries.* Geneva: WHO.

Bánóczy, J., Rugg-Gunn, A.J. and Woodward, M. (2013): Milk fluoridation for the prevention of dental caries. *Acta Medica Academica* **42**, 156-167.

Cagetti, M.G., Campus, G., Milia, E. and Lingström, P. (2013): A systematic review on fluoridated food in caries prevention. *Acta Odontologica Scandinavia* **71**, 381-387.

Jones, S., Burt, B.A., Petersen, P.E. and Lennon, M.A. (2005): The effective use of fluorides in public health. *Bulletin of the World Health Organization* **83**, 670-676.

Jürgensen, N. and Petersen, P.E. (2013) Promoting oral health of children through schools – results from a WHO global survey *Community Dental Health* **30**, 204-237.

Marino, R., Villa, A. and Geuerrero, S. (2001): A community trial of fluoridated powdered milk in Chile. *Community Dentistry and Oral Epidemiology* **29,** 453-442

Marthaler, T.M. and Petersen, P.E. (2005): Salt fluoridation - an alternative in automatic prevention of dental caries. *International Dental Journal* **55**, 351-358.

Moynihan, P. and Petersen, P.E. (2004): Diet, nutrition and the prevention of dental diseases. *Public Health Nutrition* **7** (1A), 201-226.

Pakhomov, G.N., Ivanova, K., Moller, I.J. and Vrabcheva, M. (1995): Dental caries-reducing effects of a milk fluoridation project in Bulgaria. *Journal of Public Health Dentistry* **55**, 234-237.

Patel, R. (2012): *The state of oral health in Europe*. Report commissioned by the Platform for Better Oral Health in Europe. www.oralhealthplatform.eu/sites/default/files/field/document/report - the state of oral health in europe.pdf

Petersen, P.E. (2005): Socio-behavioural risk factors in dental caries – international perspectives. *Community Dentistry and Oral Epidemiology* **33**, 274-279.

Petersen, P.E. (2008): World Health Organization global policy for improvement of oral health – World Health Assembly 2007. *International Dental Journal* **58**, 115-121.

Petersen, P.E., Bourgeois, D., Ogawa, H., Estupinan-Day, S. and Ndaiya, C. (2005).The global burden of oral diseases and risks to oral health. *Bulletin of the World Health Organization* **83**, 661-669.

Petersen, P.E. and Lennon, M.A. (2005): Effective use of fluorides for the prevention of dental caries in the 21st century: the WHO approach. *Community Dentistry and Oral Epidemiology* **32**, 319-321.

United Nations Development Programme (2002): Human development report 2002, New York: UNDP, 2002.

Woodward, S.M. (2009): The implementation of community based programmes. In Bánóczy, J., Petersen, P.E., and Rugg-Gunn, A.J. *Milk Fluoridation for the Prevention of Dental Caries.* Geneva: WHO.

World Health Organization (1994). *Fluoride and Oral Health. WHO Technical Report Series 846.* Geneva: WHO.

World Health Organization (1997) *Oral health surveys. Basic methods. 4th ed.* Geneva: WHO.

World Health Organization (1999): *Health21- Health for all in the 21st century*. Copenhagen: WHO Regional Office for Europe.

World Health Organization (2003): *Diet, Nutrition and the Prevention of Chronic Diseases. WHO Technical Report Series 916.* Geneva: WHO.

World Health Organization (2007): *World Health Assembly. Oral health: action plan for promotion and integrated disease prevention WHA60.17*. Geneva: WHO.

World Health Organization (2011): *Global status report on noncommunicable diseases 2010.* Geneva: WHO.

World Health Organization (2013): *Dental caries experience of 12-year-old children in Europe*. Copenhagen: WHO Regional Office for Europe.

World Health Organization (2014): *WHO Global Oral Health Data Bank.* Malmo, Sweden www.who.int/oral_health

World Health Organization (2015). Guideline: Sugars intake for adults and children. Geneva: WHO.

Yeung, C.A, Hitchings, J.L, Macfarlane, T.V, Threlfall, A.G, Tickle, M. and Glenny, A.M. (2005): Fluoridated milk for preventing dental caries. *The Cochrane Database of Systematic Reviews 2005*, issue 3. Art. No. CD003876.