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Symptoms experienced during periods of actual and supposed water fluoridation

Matti Lamberg[1], Hannu Hausen[2] and Terttu Vartiainen[3]

[1]Oral and Maxillofacial Unit, Department of Otolaryngology, Kuopio University Hospital, Kuopio, [2]Department of Community Dentistry, Institute of Dentistry, University of Oulu and Oulu University Hospital, Oulu and [3]The National Public Health Institute, Kuopio, Finland

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Abstract – Fluoridation of water is a controversial measure because of the suspicion that it has harmful effects on health. Opinions differ as to the reality of these fears. In Kuopio, after distressing disputes over the fluoridation issue, the City Council decided to stop fluoridation at the end of 1992. In fact, however, it was discontinued at the end of November, one month early, without the public being told. The aim of this study was to find out whether the occurrence of 25 selected symptoms was connected with exposure to fluoridated water. In order to do this we compared the prevalence of symptoms during the months before and after the undisclosed cessation of fluoridation and after the cessation had been officially announced. Postal inquiries concerning symptoms were sent to 1000 randomly selected adults in November, to a further 1000 in December 1992 and again to the same 2000 people in March 1993. The response rates were 40–26%. The percentage of those with two or more symptoms was the same (45%) in November and in December but decreased to 32% in March. The mean number of symptoms per respondent decreased from 1.9 in November to 1.4 in March ($P<0.001$) and in December-March from 1.8 to 1.2. The decrease was most significant for symptoms related to the skin. Since the occurrence and mean number of symptoms were fairly similar during actual and supposed fluoridation, the results do not support the theory that the symptoms considered in this study are caused by the physical effect of fluoridated water. On the other hand, the significant reduction in the number of symptoms only after the respondents had become aware of the discontinuation of fluoridation reveals that fluoridation may have psychological effects which present as perceived symptoms.

Key words: adverse drug reaction; allergy to fluoride; attitudes toward fluoridation; fluoridation; fluoridation controversy

Matti Lamberg, Oral and Maxillofacial Unit, Kuopio University Hospital, P.O. Box 1777, FIN-70211 Kuopio, Finland

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The fluoridation of water has been one of the most controversial measures in the history of public health practice (1), with the predominant concerns in anti-fluoridation campaigns usually being ideological. Adding fluoride to drinking water has been regarded as an unwarranted infringement of individual rights (2). For many people, however, this suspicion arises from the belief that fluoridation has harmful and adverse side effects. Most medical and dental professionals are convinced that there is no credible evidence that water containing optimal concentrations (0.7–1.2 mg/l) of fluoride has an impact on general health (3). There are, however, researchers who say that in a certain segment of the population this fluoridation practice can cause symptoms of allergy and intolerance (4, 5). One of the most comprehensive reviews of the so-called "fluoridation controversy" was published recently (6).

Kuopio, a town with 83 000 inhabitants where the communal water supply had been fluoridated (1.0 mg/l) since 1959, is the only place in the Nordic countries to have had such a fluoridation program. As in numerous similar situations, fluoridation has widely been claimed to be responsible for various ailments among Kuopio residents. The repeated anti-fluoridation campaigns, with the accompanying bitter local disputes, became so intense that the City Council decided to discontinue fluoridation at the end of 1992. The public was well informed about the time of discontinuation, and the announcement attracted much local media attention. This decision provided a unique oppor-

tunity to study whether, as claimed, there had been harmful effects.

The basic idea was to discontinue fluoridation of the water earlier without informing the public, and to study the occurrence of various symptoms among a group of people who believed that the piped water was fluoridated even though no fluoride was being added at that time. This group was compared with a group of users of fluoridated water who were well aware of the fluoridation of their piped water. Each of these groups was asked again about the presence of symptoms when the water was no longer fluoridated and the respondents knew this. If the symptoms were associated with the physical effects of fluoridation, they should have been most common at the time when the water was fluoridated and less frequent when there was no fluoridation, regardless of whether the respondents knew about the true fluoridation status. If, on the other hand, the symptoms were associated only with the perceived harmfulness of fluoridation, they should have been more frequent when people believed that the water was fluoridated and less frequent when the opposite was true, regardless of the actual fluoridation status.

Table 1. Distribution of respondents (*n*) and response rate (%) by age and sex. *N* indicates the number of subjects included in the sample

		All respondents						Respondents of both inquiries			
		Nov *N*=1000		Dec *N*=1000		Mar *N*=2000		Nov–Mar *N*=1000		Dec–Mar *N*=1000	
Age (years)	Sex	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
25–44	Male	38	28	45	32	73	27	19	14	25	18
	Female	47	41	46	35	89	36	27	23	26	20
	Total	85	34	92*	34	163*	31	46	18	51	19
35–44	Male	39	28	39	28	79	29	19	14	25	18
	Female	59	43	43	36	93	36	41	30	30	25
	Total	99*	36	83*	32	173*	33	60	22	55	21
45–54	Male	47	38	50	45	86	37	31	25	32	29
	Female	69	52	42	37	89	36	44	33	29	25
	Total	116	45	92	41	176*	37	75	29	61	27
55–64	Male	41	42	47	46	95	48	33	34	36	35
	Female	56	46	85	60	127	48	46	37	57	40
	Total	97	44	132	54	222	48	79	36	93	38
Total	Male	165	34	181	37	333	34	102	21	118	24
	Female	231	45	216	42	398	39	158	31	142	28
	Total	397*	40	400*	40	734*	37	260	26	260	26

* The slight discrepancy is due to missing data on age and/or sex.

Table 2. Mean age (SD) of the respondents by sex

	All respondents						Respondents of both inquiries			
	Nov *n*=397		Dec *n*=400		Mar *n*=734		Nov–Mar *n*=260		Dec–Mar *n*=260	
Sex	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	%	$\bar{x}$	SD	$\bar{x}$	SD
Male	45.1	11.4	45.2	11.6	45.7	11.4	47.4	11.3	46.5	11.4
Female	45.2	11.0	47.4	12.5	46.1	12.1	46.3	11.1	48.1	12.2
Total	45.1	11.2	46.4	12.2	45.9	11.8	46.8	11.2	47.3	11.9

Methods

Subjects

Fluoridation in Kuopio was discontinued at the end of November 1992, not at the end of December as people supposed. In this questionnaire study three separate inquiries were sent, each of them to a random sample taken from all 25–64-year-old residents of Kuopio living in the area included in the water fluoridation program. The first inquiry was sent in November 1992, when the water was still fluoridated and the residents were aware of this. A second similar inquiry was sent in December, 3 weeks after the premature discontinuation of fluoridation, which had not been announced to the public. The third inquiry was sent in March 1993 when it was generally known that fluoridation had been discontinued. The first two inquiries were sent to independent samples of 1000 inhabitants, and the third to all 2000 recipients of the first questionnaire. Table 1 gives the group-specific distributions of respondents by age and sex and the corresponding response rates. Table 2 shows the mean ages of the respondents in the same groups by sex.

Questionnaires

The inquiries included questions about the perceived presence or absence of 25 symptoms during the week of inquiry, water consumption patterns, perceived quality of water, opinions concerning water fluoridation and demographic data. The questions were identical in all three inquiries.

Assessment of true fluoridation status

The fluoride concentration of the water was monitored daily with ion chromatography (Dionex 2010, HPIC AG4A/N 037042 pre-column connected to HPIC AS4AP/N 07041 column, flow rate 1.7 ml/min of 0.75 mM $NaHCO_3$:n/2.0 mM Na_2CO_3:n) during the weeks of inquiries. The level of fluoride was 1.01–1.30 mg/l in November, 0.05–0.12 mg/l in December, and <0.05 mg/l in March. The last figure is equal to the fluoride level in the natural water source of the town, but in December traces of fluoridated water still remained in the water pipes.

Statistical analysis

First, the proportions of subjects reporting the given symptoms were calculated for all respondents of the November, December and March inquiries. The statistical significance of the difference between the symptoms reported in November and December was evaluated by ordinary chi-square tests. In the second set of analyses, only those who responded to both inquiries (either November and March or December and March) were included. For each of

the symptoms, a 2×2 table was formed on the basis of the presence or absence of the symptom reported in the two inquiries. McNemar tests were used to evaluate the differences between the two points in time. In addition, a summary of the symptoms reported to be present was made for each respondent on both occasions. McNemar tests were also used to evaluate the change in the proportion of subjects reporting a given number of symptoms in the consecutive inquiries. The differences in the mean number of symptoms between the two inquiries were evaluated by paired *t*-tests. The possibility of a confounding effect due to age or sex or both on the observed differences in the mean number of symptoms was checked by multivariable regression analysis. For the McNemar tests, StatXact software was used. All other analyses were performed with SPSS software.

Results

When all respondents of the three separate inquiries were considered (Table 3), it was found that the five most frequent symptoms in every survey were dryness and itching of the skin, headache, and pains in muscles and in joints. In general, men and women were equally often symptom free. However, women reported headache and dryness of the skin slightly more often than men did. Joint pain was more common among older (>44 years) than among younger respondents. Otherwise, the associations between the occurrence of symptoms and age and sex were nonsignificant (age- and sex-specific results do not appear in the table). Taken altogether, two-thirds of the recorded symptoms were slightly more rare in December than in November. For one-third of the symptoms, the situation was the opposite. However, the difference was statistically highly significant for only one symptom, "other skin rash", which appeared more often in November than in December. Of the 25 symptoms, 24 were more rare in March than in November. In the December-March comparison 22 symptoms were more rare in March.

The rest of the results concern only those who responded to both inquiries (November-March or December-March, Table 3). In both the November-March and December-March comparisons, none of the symptoms was significantly more frequent in March than in the previous inquiry; and the proportion of respondents reporting no symptom was significantly higher in March than in November or December. In the November-March comparison, three symptoms (dryness and itching of the skin, and pain in joints) were significantly less fre-

Table 3. Percentage of respondents reporting symptoms listed in the inquiries. For respondents of two inquiries (November and March or December and March) + indicates the presence of the symptom, and – its absence. E.g., the column "Nov + Mar –" gives the percentage of those who reported the symptom in November but not in March

	All respondents			Respondents of both inquiries							
				Nov–Mar n=260				Dec–Mar n=260			
	Nov n=397	Dec n=400	Mar n=734	Nov+ Mar+	Nov+ Mar–	Nov– Mar+	Nov– Mar–	Dec+ Mar+	Dec+ Mar–	Dec– Mar+	Dec– Mar–
Joint pain	13.6	13.5	10.9	6.2	9.2[d]	3.1	81.5	8.8	5.0	3.1	83.1
Muscular pain	14.1	13.3	12.5	3.5	7.3	7.7	81.5	5.8	6.2	7.7	80.4
Muscular tic (myokymia)	4.3	3.0	2.7	0.4	4.6	1.9	93.1	0.0	1.9	1.5	96.5
Muscular weakness	2.0	1.5	1.5	1.2	0.8	0.4	97.7	0.0	0.8	0.0	99.2
Difficult breathing (dyspnea)	5.5	3.8	3.7	2.3	3.1	1.2	93.5	1.5	2.7	1.2	94.6
Pain in the chest	5.8	4.3	3.5	2.7	2.7	1.2	93.5	1.2	3.1	0.8	95.0
Headache	15.9	16.8	12.9	7.7	8.1	7.7	76.5	5.8	11.2[c]	5.0	78.1
Dizziness (vertigo)	7.1[a]	3.8	3.5	1.2	5.4	3.8	89.6	0.0	2.7	1.9	95.4
Numbness	6.8	5.8	5.9	2.7	5.0	5.0	87.3	1.2	3.8	3.1	91.9
Visual disturbance	3.3	2.3	1.8	0.4	1.5	1.5	96.5	0.0	1.5	1.2	97.3
Tinnitus	7.3	6.8	6.4	3.5	5.4	5.0	86.2	2.7	4.2	2.3	90.8
Depression	6.5	5.3	4.0	0.8	5.0	2.3	91.9	1.5	4.2	1.9	92.3
Insomnia	8.1	11.5	5.6	2.3	5.4	2.7	89.6	3.1	6.5	2.7	87.7
Epigastric pain or heartburn	11.6	8.5	7.8	2.7	6.2	7.3	83.8	2.7	5.0	2.3	90.0
Nausea or vomiting	3.8	2.3	1.1	0.4	3.1	0.8	95.8	0.0	2.3[c]	0.0	97.7
Diarrhea	4.5	6.8	3.8	1.5	1.9	3.1	93.5	1.5	5.0[c]	1.5	91.9
Constipation	2.3	3.3	2.2	0.4	1.5	0.8	97.3	0.8	1.5	1.9	95.8
Dysuria	2.0	1.5	1.1	0.0	1.9	0.8	97.3	0.8	1.2	0.8	97.3
Pain in the mouth or tongue	3.3	4.3	2.5	0.8	2.3	2.7	94.2	0.4	5.8	2.3	91.5
Nettle rash (urticaria)	1.3	0.5	1.5	0.0	0.8	0.8	98.5	0.0	0.8	0.8	98.5
Other skin rash (eczema)	10.6[b]	4.3	4.9	2.7	6.2	3.1	88.1	1.2	2.7	2.7	93.5
Itching of the skin	21.2	19.8	13.5	6.5	13.8[c]	5.4	74.2	5.0	13.1	7.7	74.2
Dryness of the skin	29.7	32.0	14.9	9.2	17.3[c]	5.0	68.5	11.2	19.6[c]	4.2	65.0
Smarting of the eyes	8.1	11.8	5.9	1.9	4.6	4.2	89.2	2.3	10.0[c]	3.1	84.6
Exceptional fatigue	6.3	5.8	5.4	1.9	5.0	2.3	90.8	1.2	5.0	4.2	89.6
Other symptom(s)	2.3	3.0	2.7	0.0	2.7	2.3	95.0	0.4	3.5	1.2	95.0
None of the above symptoms	36.5	34.5	50.1	29.2	8.8[c]	21.2	40.8	30.4	6.5[c]	22.7	40.0

[a] $P<0.05$, [b] $P<0.001$, November vs. December, by chi-square test; [c] $P<0.05$, [d] $P<0.01$, [e] $P<0.001$, 1st vs. 2nd inquiry, by the McNemar test.

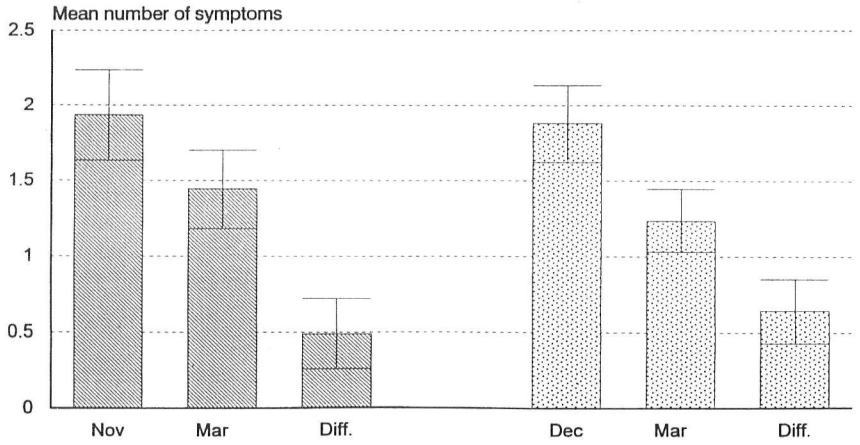

Fig. 1. Mean numbers of reported symptoms and mean difference (Diff.) in number of symptoms between the two inquiries (with their 95% confidence intervals) among the November-March group (n=260) and the December-March group (n=260). Only those who responded to both inquiries are included.

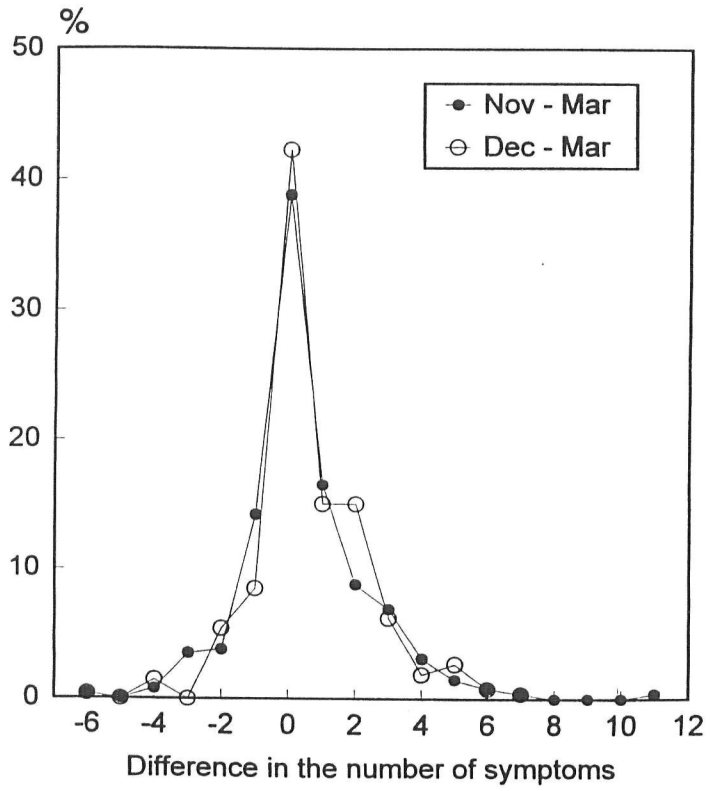

Fig. 2. Distribution of subjects according to difference in number of symptoms between the first and the second inquiry among the November-March group (n=260) and the December-March group (n=260).

quent in March ($P<0.01$). Correspondingly, in the December-March comparison, five symptoms (dryness of the skin, smarting of the eyes, headache, nausea, and diarrhea) were less frequent in March ($P<0.05$).

For both the November-March and the December-March comparisons, the proportion of respondents reporting at least one symptom was lower in the second than in the first inquiry. The reduction was even clearer for the proportion of respondents with three or more symptoms (November vs. March, $P<0.01$; December vs. March $P<0.001$). For both comparisons, the patterns of distribution were almost the same.

Fig. 1 shows the mean numbers of reported symptoms and the mean differences between the two consecutive inquiries. For both comparisons, the mean was clearly lower in March ($P<0.001$). The reductions in the two comparisons did not differ significantly. The pattern of the distribution of subjects according to the difference in number of symptoms between the consecutive inquiries was virtually identical in both comparisons (Fig. 2). Multivariable regression analysis revealed that the difference between the first and second inquiries was not related to age or sex.

In the November-March group, the taste of fluoride in water was reported to be detectable by 9.6% of the respondents in November and by 0.0% (none) in March. The corresponding figures for the December-March group were 9.6% and 0.4% (one respondent). In November, the mean number of symptoms was 1.8 (SD 2.3) for those reporting no taste of fluoride and 3.2 (SD 3.3) for those who reported tasting fluoride ($P<0.05$). This difference persisted in March, the mean number of symptoms being 1.4 (SD 2.2) and 1.7 (SD 1.9) for non-tasters and tasters, respectively (NS). Thus the reduction in the number of symptoms between the consecutive inquiries was significantly higher among those who reported tasting fluoride in November ($P<0.05$). A similar pattern was found for the December-March group.

In the first inquiry, 39% of the respondents in the November-March group considered fluoridation to be a good thing, 20% considered it bad, and 41% had no opinion. The respective percentages in the December-March group were 45%, 15%, and 40%. In both groups the mean number of symptoms was lower among those who considered fluoridation to be good than among those who thought it was bad or who had no opinion. Despite the similarity of the pattern, the difference among the three categories was statistically significant only for the December-March group (December $P<0.001$ and March $P<0.01$).

Discussion

Compared to the usual response rates in Finnish postal questionnaires, the

rates of return in this study were clearly lower. The shortness of the available survey time during the supposed fluoridation in December made it impossible to send reminders to non-respondents. For the sake of comparability, reminders were also omitted in November and March. The distribution of the respondents by age and sex (Table 1) reveals that response rates were higher among women and older people, and thus the study samples were not truly representative of the target population. Consequently, the percentages of respondents reporting different symptoms must not be taken as valid estimates for the whole population. However, since the same subjects were questioned in the November-March and in the December-March comparison, intra-group comparisons were not biased according to age and sex. The similarity of the age and sex distribution of the November-March and December-March groups ensured that comparisons between these two groups were not biased by age or sex or both.

Judging from accidental mass intoxications with fluoride, we know that virtually every organ in the human body can be affected by fluoride, with gastrointestinal symptoms prevailing (7). Even if the situation is totally different with the "physiological" anti-caries concentrations of fluoride added to water supplies, concerns about health problems from fluoridation are expressed repeatedly. Opinions differ even among physicians and researchers, not to mention lay people. The often suspected dermatological effects of fluoride exposure seem to consist of toxic rather than allergic reactions (8). The power of suggestion as a source of various symptoms has been vividly demonstrated on several occasions where fluoridation has been started later than people have believed (9). The role of the psychological vs. the biological origin of perceived symptoms has not, to our knowledge, previously been studied in this type of large-scale survey.

The results obtained were mostly expected and, in our opinion, quite convincing. Since the prevalence of the symptoms considered was fairly similar in November and in December, despite the fact that there was no water fluoridation in December and even though people believed that there was, the results do not support the theory that the symptoms would be caused by the physical effect of being exposed to fluoridated water.

The possibility that seasonal variation could have caused the reduction in the occurrence of symptoms between November and March, and between December and March could not be controlled for in the current experimental design. This is unlikely, however, since in the Kuopio area all three are clearly winter months. In addition, the prevalence of symptoms was significantly reduced only after the respondents had become aware of the discontinuation of fluoridation, which reveals that if fluoridation does affect the perception of symptoms, that effect must be mainly psychological.

Even after massive intoxication with fluoride, symptoms usually last only 2–3 weeks (7). During the survey week in December, the fluoride concentration had been at its natural level for 3 weeks. Thus, any symptoms that may have been caused by fluoride should have disappeared but apparently had not. However, when the groups that responded to both inquiries were analyzed, the decrease in the mean number of symptoms from times of actual and supposed fluoridation to actual discontinuation of fluoridation was the same. In both inquiries the respondents in the December group reported being slightly healthier than those in the November group. Thus the smaller number of symptoms in December probably was not caused by cessation of fluoridation. However, the significant decrease in the number of other skin rashes leaves room for speculation, seeming to favor the view that a small segment of the population may have some kind of intolerance to fluoride. This group of people should be studied further.

The most frequently reported symptoms that disappeared from the time of actual to known discontinuation of fluoridation seemed to be itching and dryness of the skin. The same was true, however, for the period from supposed to known discontinuation of fluoridation. The most frequently perceived symptoms were those that are often linked with the so-called psychosomatic diseases.

Although it is obviously impossible for humans to taste fluoride in the concentrations present in fluoridated water (10), nearly 10% of the respondents reported doing so. However, the respondents made this claim equally often during actual and supposed fluoridation. As expected, the percentage reporting this "fluoride taste" dropped to nearly zero during known discontinuation of fluoridation in March. The psychological aspect is further confirmed by the fact that the illusory tasters seemed to be predisposed to perceived symptoms, as were also those who regarded fluoridation as a bad practice in general. In conclusion, it seems likely that the prevalence of the symptoms considered in the current study is connected with the psychological rather than with the physical effects of being exposed to fluoridated water.

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