

JUSTYNA OPYDO-SZYMACZEK

Fluoride Exposure from Diet in Infants and Young Children Fed with the Foodstuffs for Particular Nutritional Use*

Ekspozycja na fluorki zawarte w diecie niemowląt i małych dzieci karmionych środkami spożywczymi specjalnego przeznaczenia żywieniowego

Department of Pediatric Dentistry, Poznan University of Medical Sciences, Poland

Abstract

Background. The association between excessive fluoride ingestion during early childhood and dental fluorosis has been widely reported in literature.

Objectives. The aim of the study was to estimate how much foodstuffs for particular nutritional use effect children's daily fluoride exposure.

Material and Methods. Results of the own analyses of fluoride content in milk formulas, beverages and ready-to-eat foods in jars, as well as current recommendations on the young children's feeding were used in the calculation.

Results. The study revealed that if milk formula is reconstituted in water containing more than 0.5 ppm of fluoride, some infants will exceed their recommended upper tolerable intake level of fluoride. Beverages containing tea extract may contribute a substantial amount to daily fluoride intake.

Conclusions. There is a need of monitoring of fluoride content in foodstuffs for children and presenting the level of fluoride on the product's label. Results also indicate that there is a necessity of spreading the recommendation on preparation of milk formula with the use of low-fluoride water. Since some dietary components may be a significant source of fluoride, they should be considered in the assessment of daily fluoride exposure, especially when the methods of fluoride prophylaxis are to be introduced in the patient (*Dent. Med. Probl.* 2012, 49, 2, 209–215).

Key words: fluoride, foods and beverages, children.

Streszczenie

Wprowadzenie. W piśmiennictwie istnieje wiele doniesień na temat związku między nadmierną ekspozycją na fluorki w okresie wczesnego dzieciństwa a fluorozą szkliwa.

Cel pracy. Ocena wpływu spożycia środków spożywczych specjalnego przeznaczenia żywieniowego na dobową ekspozycję dzieci na fluorki.

Materiał i metody. W ocenie wykorzystano wyniki badań własnych oceniających stężenia fluorków w mlekach modyfikowanych, napojach i gotowych do spożycia pokarmach w słoiczkach oraz obecne rekomendacje dotyczące żywienia małych dzieci.

Wyniki. Badania wykazały, że przygotowanie mleka modyfikowanego na bazie wody o zawartości fluorków większej niż 0,5 ppm może spowodować zwiększenie dziennej podaży fluorków powyżej górnego tolerowanego poziomu spożycia. Napoje z dodatkiem ekstraktu z herbaty prawdziwej mogą znacząco zwiększać dobową ekspozycję na fluorki.

Wnioski. Istnieje potrzeba monitorowania stężeń fluorków w środkach spożywczych przeznaczonych dla dzieci oraz zamieszczania informacji o zawartości fluorków na etykietach produktów. Wyniki wskazują także na konieczność rozpowszechniania zalecenia odnośnie do przygotowywania mleka modyfikowanego na bazie wody z małą zawartością fluorków. Ponieważ niektóre składniki diety mogą być znaczącym źródłem fluorków, dlatego należałoby uwzględnić je w ocenie dobowej ekspozycji, zwłaszcza przy ustalaniu wskazań do objęcia pacjenta profilaktyką fluorkową (*Dent. Med. Probl.* 2012, 49, 2, 209–215).

Słowa kluczowe: fluorki, pokarmy i napoje, dzieci.

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The role of fluorides in the prevention of dental caries is undeniable. Widespread use of fluoridated water, fluoride dentifrice, dietary fluoride supplements and other forms of fluoride has been associated with a great decline in the prevalence of dental caries in many economically developed populations [1].

However, ingestion of excessive fluoride during tooth development can cause structural changes in tooth enamel. The resulting condition, dental fluorosis, in its mildest form, presents as tiny white lines running across the teeth, in advance stages as brown stains, as well as cracking and pitting of the enamel. Dental fluorosis is caused by cumulative fluoride intake during enamel development. The critical period for development of fluorosis in permanent maxillary central incisors is from 4 months to 4 years of age. Thus, excessive fluoride intake must occur during early childhood, to affect the most aesthetically important teeth [1–3].

All sources of fluoride exposure are important since they contribute to the total intake which

is critical in the development of fluorosis. Apart from unintentionally swallowed fluoridated toothpaste, various children's diet compounds, such as milk formulas, foods containing chicken and fish, some bottled waters and beverages, were identified as significant sources of ingested fluoride [1–7].

The purposes of this paper are to describe fluoride intake from Polish foodstuffs for particular nutritional uses intended for infants and young children and to assess how much these foods effect daily fluoride exposure of infants and toddlers aged 1, 6, 12 and 18 months.

Material and Methods

Calculations of fluoride intake were based on the results of the own analyses of fluoride content in breast milk substitutes, beverages and ready-to-eat foods in jars performed with the use of fluoride ionselective fluoride electrode (09–37 type) (MARAT) (Table 1) [8–10], as well as on the cur-

Table 1. Fluoride content in various types of beverages, infant and toddler formulas and foods containing chicken or fish [8–10]

Tabela 1. Zawartość fluorków w różnych typach napojów, mlekach modyfikowanych dla niemowląt i małych dzieci oraz posiłkach zawierających mięso kurczaka i ryby [8–10]

Type of the product (Typ produktu)	Fluoride content – mg/l (Zawartość fluorków)
Starting formula after dilution in distilled water (Mleko początkowe przygotowane na bazie wody destylowanej)	0.024–0.068
Follow-on formula after dilution in distilled water (Mleko następne przygotowane na bazie wody destylowanej)	0.013–0.069
Toddler formula after dilution in distilled water (Mleko typu „junior” przygotowane na bazie wody destylowanej)	0.018–0.111
Fruit juices (Soki owocowe)	0.01–0.29
Instant beverages without tea extract for children aged 6 months after dilution in distilled water (Herbatki granulowane bez ekstraktu z herbaty prawdziwej dla dzieci 6-miesięcznych przygotowane na bazie wody destylowanej)	< 0.01–0.05
Instant beverages with tea extract for children aged 6 months after dilution in distilled water (Herbatki granulowane z ekstraktem z herbaty prawdziwej dla dzieci 6-miesięcznych przygotowane na bazie wody destylowanej)	0.08–0.11
Instant beverages without tea extract for children aged 12–18 months after dilution in distilled water (Herbatki granulowane bez ekstraktu z herbaty prawdziwej dla dzieci 12–18-miesięcznych przygotowane na bazie wody destylowanej)	< 0.01–0.19
Instant beverages with tea extract for children aged 12–18 months after dilution in distilled water (Herbatki granulowane z ekstraktem z herbaty prawdziwej dla dzieci 12–18-miesięcznych przygotowane na bazie wody destylowanej)	0.08–1.14
Mixed foods in jar containing fish (Posiłki mieszane w słoiczkach zawierające mięso ryby)	0.16–0.44
Chicken meat in jar (Mięso kurczaka w słoiczku)	0.57–1.06
Mixed foods in jars containing chicken (Posiłki mieszane w słoiczkach zawierające mięso kurczaka)	0.12–0.57
Turkey meat in jar (Mięso z indyka w słoiczku)	0.44–0.74
Mixed foods in jars containing turkey (Posiłki mieszane w słoiczkach zawierające mięso indyka)	0.15 –0.35 mg/kg

rent recommendations on the young children's feeding [11–13]. Ranges of fluoride intake from foodstuffs for particular nutritional uses were presented together with optimal fluoride intake and upper tolerable intake level of fluoride calculated for average body weights of Polish children aged 1, 6, 12 and 18 months [14–16].

Results

Tables 2–4 present calculated ranges of fluoride intakes from foods and beverages mentioned above, taking into account the fluoride content of water used for reconstitution of the instant products together with optimal fluoride intake and upper limit of fluoride intake of children aged 1, 6, 12 and 18 months. Table 5 presents range of the total daily fluoride intake from foodstuffs for particular nutritional uses, optimal fluoride intake and upper limit of fluoride intake of children aged 1, 6, 12 and 18 months.

Discussion

In 1997, the Institute of Medicine released upper limit recommendations for dietary intake of fluoride. These upper limits were based on an av-

erage, chronic daily fluoride intake of 0.10 mg/kg b.w., which seemed to be the threshold beyond which moderate enamel fluorosis might appear in some children [15]. However, Fomon et al. [3], who analyzed children's feeding habits associated with the risk of dental fluorosis, suggest striving for intakes less than 0.07 mg F/kg b.w. The range of 0.05 to 0.07 mg F/kg b.w. has been commonly quoted in literature as 'optimal' for dental health in children aged from 1 to 12 years [3, 16].

Since breast milk contains low concentration of fluoride (mean 0.01 ppm), breastfed infants receive only about 0.01 mg of fluoride daily [15, 17]. The results of the study by Brothwell and Limeback [18] suggest that breastfeeding helps to protect against dental fluorosis both in fluoridated and non-fluoridated communities. Although, according to current European legislation [19], infant formulae must also contain low fluoride levels, problems arise if powdered concentrate is mixed with fluoridated water. Then, in children who use formula as a primary source of nutrition, fluoride intake may exceed the recommended upper limits [1, 3, 20].

In Poland drinking water is not artificially fluoridated. The study by Czarnowski et al. [21] on fluoride content in 94 localities in Northern and Central Poland revealed that in 62 studied localities fluoride concentration in drinking water was

Table 2. Fluoride intake (FI) from formula reconstituted in water containing various fluoride levels, optimal fluoride intake (OI) and upper tolerable intake level (UL) calculated for average body weight (BW) of children 1, 6, 12, 18 months of age

Tabela 2. Spożycie fluorków (FI) z mlekiem modyfikowanym przygotowanym na bazie wody z różnymi stężeniami fluorków, optymalne spożycie (OI) i górny tolerowany poziom spożycia (UL) obliczone dla średnich mas ciała (BW) dzieci w wieku 1, 6, 12, 18 miesięcy

Age – month (Wiek – miesiące)	BW ^a kg	OI ^b mg	UL ^c mg	FI ^d mg		
	girls boys			0.0–0.3 ppm	0.4–0.5 ppm	0.6–1.0 ppm
1	4.3	0.22–0.30	0.43	0.02–0.26	0.24–0.40	0.35–0.75
	4.6	0.23–0.32	0.46			
6	7.5	0.38–0.53	0.75	0.01–0.31	0.33–0.47	0.50–0.87
	8.2	0.41–0.57	0.82			
12	9.5	0.48–0.67	0.95	0.01–0.22	0.24–0.34	0.36–0.64
	10.2	0.51–0.71	1.02			
18	11	0.55–0.77	1.1	0.01–0.25	0.25–0.36	0.36–0.66
	12	0.6–0.84	1.2			

^a 50th percentile (50. percentyl) [14].

^b 0.05–0.07 mg/kg b.w. [164].

^c 0.1 mg/kg b.w. [153].

^d Calculation on the basis of the range of fluoride content in mother's milk substitutes [8] assuming that 1 month old infant drinks 630–770 ml of starting formula daily, 6 months old 900 ml of starting or follow-on formula daily, 12 months old 660 ml of follow-on formula daily and 18 months old 650 ml of toddler formula daily [11, 120].

^d Obliczenia na podstawie zakresu stężeń fluorków w substytutach mleka matki, zakładając, że miesięczne niemowlę pije dziennie 630–770 ml mleka początkowego, 6-miesięczne 900 ml mleka początkowego lub następnego, 12-miesięczne 660 ml mleka następnego, a 18-miesięczne dziecko 650 ml mleka typu „junior”.

Table 3. Fluoride intake from juices (FIJ) and tea beverages (FIT) reconstituted in water containing various fluoride levels, optimal fluoride intake (OI) and upper tolerable intake level (UL) calculated for average body weight (BW) of children 1, 6, 12, 18 months of age

Tabela 3. Spożycie fluorków z sokami (FIJ) i herbatkami (FIT) przygotowanymi na bazie wody zawierającej różne stężenia fluorków, optymalne spożycie (OI) i górne tolerowany poziom spożycia (UL) obliczone dla średnich mas ciała (BW) dzieci w wieku 1, 6, 12 i 18 miesięcy

Age – month (Wiek – miesiące)	BW ^a kg	OI ^b mg	UL ^c mg	FIJ ^d mg	FIT ^d mg		
	girls boys				0.0–0.3 ppm	0.4–0.5 ppm	0.6–1.0 ppm
1	4.3	0.22–0.30	0.43	n.a.	n.a.	n.a.	n.a.
	4.6	0.23–0.32	0.46				
6	7.5	0.38–0.53	0.75	0.0–0.04	0.0–0.06	0.02–0.09	0.03–0.17
	8.2	0.41–0.57	0.82				
12	9.5	0.48–0.67	0.95	0.0–0.04	0.0–0.22	0.02–0.25	0.03–0.32
	10.2	0.51–0.71	1.02				
18	11	0.55–0.77	1.1	0.0–0.05	0.0–0.26	0.05–0.30	0.07–0.39
	12	0.6–0.84	1.2				

^a 50th percentile (50. percentyl) [14].

^b 0.05–0.07 mg/kg b.w. [16].

^c 0.1 mg/kg b.w. [15].

^d Calculation on the basis of the range of fluoride content in juices and beverages [9] assuming that 6–12 month old infants drink 50–150 ml of juice or beverage daily, 18 month old toddler drinks 120–180 ml of juice or beverage daily [11–13].

^d Obliczenia na podstawie zakresu stężeń fluorków w sokach i herbatkach, zakładając, że 6–12-miesięczne niemowlę pije dziennie 50–150 ml soku lub herbatki, a 18-miesięczne dziecko pije 120–180 ml soku lub herbatki.

Table 4. Fluoride intake from ready-to-eat foods in jars (FI), optimal fluoride intake (OI) and upper tolerable intake level (UL) calculated for average body weight (BW) of children 1, 6, 12, 18 months of age

Tabela 4. Spożycie fluorków z gotowymi do spożycia posiłkami w słoiczkach (FI), optymalne spożycie (OI) i górny tolerowany poziom spożycia (UL) obliczone dla średnich mas ciała (BW) dzieci w wieku 1, 6, 12 i 18 miesięcy

Age – months (Wiek – miesiące)	BW ^a kg	OI ^b mg	UL ^c mg	FI ^d mg
	girls boys			
1	4.3	0.22–0.30	0.43	n.a.
	4.6	0.23–0.32	0.46	
6	7.5	0.38–0.53	0.75	< 0.01–0.07
	8.2	0.41–0.57	0.82	
12	9.5	0.48–0.67	0.95	0.01–0.11
	10.2	0.51–0.71	1.02	
18	11	0.55–0.77	1.1	0.03–0.15
	12	0.60–0.84	1.2	

^a 50th percentile (50. percentyl) [14].

^b 0.05–0.07 mg/kg b.w. [16].

^c 0.1 mg/kg b.w. [15].

^d Calculation on the basis of the range of fluoride content in ready-to-eat foods in jars [10] assuming that 6 month old child consumes one 125g jar of mixed food containing chicken or fish daily or 10 g of cooked poultry meat daily and 12 month old child 200 g of mixed food or 20 g of cooked meat daily, 18 month old 260 g of mixed food or 45 g of cooked meat daily [11–13].

^d Obliczenia na podstawie zakresu stężeń fluorków w gotowych posiłkach w słoiczkach, zakładając, że 6-miesięczne niemowlę spożywa jeden 125 g słoiczek mieszanego posiłku zawierającego kurczaka lub rybę dziennie lub 10 g gotowanego mięsa drobiowego dziennie, 12-miesięczne 200 g posiłku mieszanego lub 20 g mięsa gotowanego dziennie, a 18-miesięczne dziecko 260 g posiłku mieszanego lub 45 g mięsa gotowanego dziennie.

Table 5. Total daily fluoride intake (FI) from milk formula, beverages and ready-to-eat foods when water containing various levels of fluoride is used for preparation of products, optimal fluoride intake (OI) and upper tolerable intake level (UL) calculated for average body weight (BW) of children 1, 6, 12, 18 months of age

Tabela 5. Całkowite dzienne spożycie fluorków (FI) z mlekiem modyfikowanym, napojami i gotowymi do spożycia posiłkami w słoiczkach, przygotowanymi na bazie wody zawierającej różne stężenia fluorków, optymalne spożycie (OI) i górny tolerowany poziom spożycia (UL) obliczone dla średnich mas ciała (BW) dzieci w wieku 1, 6, 12 i 18 miesięcy

Age – months (Wiek – miesiące)	BW ^a kg	OI ^b mg	UL ^c mg	Total FI ^d (Całkowite FI) mg		
				0–0.3 ppm	0.4–0.5 ppm	0.6–0.7 ppm
1	4.3	0.22–0.30	0.43	0.02–0.26	0.24–0.40	0.35–0.75
	4.6	0.23–0.32	0.46			
6	7.5	0.38–0.53	0.75	0.01–0.44	0.33–0.63	0.50–1.11
	8.2	0.41–0.57	0.82			
12	9.5	0.48–0.67	0.95	0.02–0.55	0.25–0.70	0.37–1.07
	10.2	0.51–0.71	1.02			
18	11	0.55–0.77	1.1	0.04–0.66	0.28–0.81	0.39–1.20
	12	0.6–0.84	1.2			

^a 50th percentile (50.y percentyl) [14].

^b 0.05–0.07 mg/kg b.w. [16].

^c 0.1 mg/kg b.w. [15].

^d Calculation based of a range of fluoride intake from formula, beverages and ready-to-eat foods in jars.

^d Obliczenia na podstawie zakresów spożycia fluorków z mlekiem modyfikowanym, napojami i gotowymi posiłkami w słoiczkach.

below 0.3 ppm, in 24 localities ranged from 0.3 to 1.0 ppm and in 8 localities exceeded 1.0 ppm (with a peak value equaled 3.0 ppm) [21].

Own studies on fluoride content in Polish breast milk substitutes confirmed that infant formula itself contains low level of fluoride, but when reconstituted in water containing more than 0.5 ppm of fluoride it may increase the daily fluoride intake of children over upper tolerable intake level [6]. Moreover, calculation revealed that in order to keep fluoride intake from formula below the upper limit of optimal fluoride intake (0.07 mg/kg b.w.), the youngest infants should be fed with the use of formula reconstituted in water containing no more than 0.3 ppm of fluoride. It is in agreement with previous recommendation of Fomon et al., who analyzed the risk of dental fluorosis associated with infant feeding practice [3].

As far as Polish beverages for children are concerned, most of them contain low level of fluoride (< 0.3 ppm), with the exception of beverages containing tea extract, which may be the significant source of fluoride intake [9]. Even when reconstituted in low-fluoride water, they may provide up to 0.26 mg of fluoride daily, which is similar dose as it would be obtained by administering of one 0.25 mg fluoride tablet. None of infant beverages however, has fluoride content listed on the label. It is noteworthy, that consumption of juices and soft drinks has increased in recent years [4]. Polish survey revealed

that 6 months of age infants consumed an average of 90 ml of juice per day and 103 ml of tea beverage per day and 12-month-olds consumed 155 ml of juice and 165 of tea beverage daily [22].

Foods in jars containing chicken or fish show wide range of fluoride content from 0.12 to 1.06 mg/kg, but as they are consumed in relatively small amounts they should not increase themselves the risk of dental fluorosis [10].

It must be remembered that all Polish food products used in present calculations are classified as foodstuffs intended for particular nutritional uses, which means that they must satisfy the nutritional requirements of infants and young children. Restrictions on pesticides residues and the use of high quality ingredients may result in relatively low levels of fluoride found in these products [23, 24]. Literature data suggest that other products consumed by children, e.g. adult juices and beverages (especially grape juice and tea beverages), sausages and meat nuggets containing mechanically deboned poultry meat may contain higher quantities of fluoride [3–5]. It is also noteworthy that calculations of the fluoride intakes were based on current recommendations on young children's feeding that may differ from real feeding habits in Poland.

Results of the study indicate that there is a necessity of spreading the recommendation on preparation of milk formula and instant beverages with the use of low-fluoride water. Since this informa-

tion should be available to the public, it would be justifiable to place it on formula container. Over two decades ago Ekstrand [20] recommended that bottled or deionized water should be used instead of fluoridated water to dilute the formula. He also reported that in some cases this recommendation had already been placed on formula packaging. If tap water contains more than 0.5 ppm of fluoride, parents may use bottled water with low level of fluoride. The own study on fluoride content of Polish bottled waters intended for infants and children, revealed that concentration of fluoride in these products did not exceed 0.3 ppm, which means that they can be safely used as diluents of infant formula [25].

Results of the present study confirm that, un-

der current conditions of increasing fluoride exposure from variety of sources, the estimation of total fluoride intake of a given population cannot be based solely on the level of fluoride in the drinking water. Moreover, so called "optimally" fluoridated water [1], seems to contain too much fluoride, to be used for preparation of infant formula and beverages [26, 27].

There is a need of monitoring of fluoride content in foodstuffs for children and it would be advisable to present the level of fluoride on the product's label [4]. Since some dietary components may be a significant source of fluoride, they should be considered in the assessment of daily fluoride exposure, especially when the methods of fluoride prophylaxis are to be introduced in the young patient.

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Address for correspondence:

Justyna Opydo-Szymaczek
Department of Pediatric Dentistry
Poznan University of Medical Sciences
Bukowska 70
60-812 Poznań
Poland
E-mail: jopydo@am.poznan.pl
Tel.: +48 61 854 70 53

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