Estimated dietary fluoride intake for New Zealanders

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Abstract

Objectives: Existing fluoride concentration and consumption data were used to estimate fluoride intakes from the diet and toothpaste use, for New Zealand sub-populations, to identify any population groups at risk of high-fluoride intake.
Methods: For each sub-population, two separate dietary intake estimates were made – one based on a non-fluoridated water supply (fluoride concentration of 0.1 mg/L), and the other based on a water supply fluoridated to a concentration of 1.0 mg/L. Fluoride concentration data were taken from historical surveys, while food consumption data were taken from national 24-hour dietary recall surveys or from simulated diets.
Results: Mean and 95th percentile estimations of dietary fluoride intake were well below the upper level of intake (UL), whether intakes were calculated on the basis of a non-fluoridated or fluoridated water supply. The use of fluoride-containing toothpastes provides additional fluoride intake. For many of the population groups considered, mean fluoride intakes were below the adequate intake (AI) level for caries protection, even after inclusion of the fluoride contribution from toothpaste. Intake of fluoride was driven by consumption of dietary staples (bread, potatoes), beverages (particularly tea, soft drinks, and beer), and the fluoride status of drinking water.
Conclusion: Estimates of fluoride intake from the diet and toothpaste did not identify any groups at risk of exceeding the UL, with the exception of infants (6-12 months) living in areas with fluoridated water supplies and using high-fluoride toothpaste. In contrast, much of the adult population may be receiving insufficient fluoride for optimum caries protection from these sources, as represented by the AI.

Introduction

Fluoride is a naturally occurring element found in water, air, soil and food (1). Fluoride is added to approximately 61 percent of community drinking water supplies (52 percent of the population) in New Zealand as a protective measure against tooth decay (2). Fluoride prevents tooth decay primarily by inhibiting demineralization of the tooth surface and inhibiting growth of cariogenic bacteria (3). It also assists in repairing the early stages of tooth decay (3).

Periodic assessments of fluoride intake from all sources are necessary as fluoride intakes above optimal levels can have negative health outcomes (1), while low-fluoride intake may result in failure to achieve dental benefits. The main sources of fluoride intake for the general population are fluoridated drinking water, diet, and toothpaste (1).

Fluoride intake from the diet can vary according to geographical location, age group and dietary habits. Changes in dietary habits over time can increase or decrease fluoride intakes (4). Estimates of dietary fluoride intake by New Zealanders were carried out as part of the 1987-1988 and 1990-1991 New Zealand Total Diet Surveys (NZTDS) (5,6).

Previous estimates of dietary fluoride intake for New Zealand are now somewhat dated, only considered average dietary intakes, and did not consider additional intake of fluoride from toothpaste or the impact of a fluoridated water supply (5,6). The current study used dietary modeling techniques to allow a fuller description of dietary fluoride intake, enabling the identification of groups that are potentially at risk of exceeding the upper level of intake (UL) for fluoride (7), and the food items contributing to any elevated intakes. The special case of fully formula-fed infants is dealt with in a separate publication (8). A more detailed description of the methodology used in the current survey can be accessed through the Internet (9). Dietary supplements also have the potential to impact significantly on fluoride intake, particularly in young children. However, as dietary fluoride supplements appear to be used infrequently in New Zealand (10), their contribution to dietary fluoride intake was not considered in the current study.

Methods

Fluoride concentrations in foods

To estimate the fluoride concentrations of New Zealand foods, results from two NZTDS (5,6) were compared. Each NZTDS analyzed a single composite sample for each food, with composites made up of equal weights of 8-10 samples, taken to represent brand, geographical and temporal variation in the food supply. When these results were in good agreement, the two results were averaged and the average used for further analysis. An arbitrary test for "good agreement" was defined as a relative standard deviation of less than 50 percent. Where the results from the two NZTDSs were not in good agreement, data from Australia (11) and the United States (12) were considered to suggest which of the NZTDS results was likely to be more reliable. If no external information was available on the particular food, the two available results were averaged and the average used for further analysis. If no New Zealand information on the fluoride content of a particular food was available, overseas data or data from similar New Zealand foods were considered. This occurred in approximately 20 percent of cases; overseas data were used to confirm the generally low fluoride content of fruits and vegetables, while New Zealand data were used to provide data from similar foods in other categories. For example, the fluoride content of "cream" was represented by the mean concentration from "ice cream" and "yoghurt."

The NZTDS methodology uses distilled water for the preparation of all foods. For the purpose of the current study, all foods that would be prepared by the addition of water in the home or that would absorb water during the cooking process (e.g., rice, pasta) had their fluoride contents recalculated based on scenarios of either typical New Zealand tap water (0.1 mg F/L), or optimally fluoridated water (1.0 mg F/L) (2). It was assumed that vegetables cooked by boiling would not acquire additional fluoride during cooking. Further details of adjustments to fluoride contents of foods due to water uptake can be found in the technical report of this study (9).

Food consumption information

Two sources were used to provide information on the food consumption patterns of New Zealanders:

Simulated diets

Simulated typical diet food consumption information was taken from the 2003-2004 NZTDS (13). The NZTDS derived simulated diets for specific population sub-groups (6-12-month-old infants, 1-3-year-old toddlers, 4-6-year-old children, 11-14-year-old children, 19-24-year-old males, and adults 25 years of age and over).

24-h dietary recall records (24HDR)

Actual food consumption information is available from the 1997 National Nutrition Survey (NNS97) conducted for New Zealanders 15 years of age and older (14) and the 2002 National Childrens' Nutrition Survey (CNS02) for children 5-14 years of age (10). These surveys include 24HDR information for almost 8,000 New Zealanders (4,636 in the NNS97 and 3,275 in the CNS02).

Estimation of dietary intake of fluoride

Total diet approach

The total diet approach to calculating dietary intakes of food components was carried out according to Vannoort and Thomson (13). This involves combination of average fluoride concentrations for foods with average amounts of the foods consumed, as specified in simulated diets.

Dietary modeling approach

Estimates of dietary intake of fluoride were made by combining average concentrations of fluoride in foods with 24HDR information from the CNS02 or the NNS97 using Microsoft FoxPro. The 24HDR records included in the NNS97 and CNS02 contain a much wider range of foods than the food lists for the 1987-1988 and 1990-1991 NZTDSs. To utilize all the food consumption data in the nutrition surveys, a mapping process was carried out to match the foods from the 1987-1988 and 1990-1991 NZTDSs to food descriptors employed in the CNS02/NNS97. For example, the total diet food "white bread" was mapped to all white breads, buns, and rolls. Mapping is a common process undertaken as part of the Australian Total Diet Survey and a more detailed discussion can be accessed by reference to reports from that study (15). Where possible, the validity of the mapping process was checked by comparisons of fluoride concentration data for mapped foods in international studies. This was only possible in about 50 percent of cases, but agreement was sufficiently good (±20 percent) to give confidence in the mapping process.

The mean amount of fluoride in each food type was multiplied by the amount of food consumed and summed over all foods to estimate the dietary fluoride intake for each individual surveyed in the CNS02/NNS97.

The complete set of dietary intake estimates was further sub-divided to provide information on sub-groupings

Table 1 Estimated dietary intake of fluoride for New Zealanders

			Mean estimated dietary fluoride intake (95th percentile*) (mg/day)				Mean estimated fluoride intake from toothpaste (mg/day)†	
	Reference values (mg/day)		Total diet		Dietary modeling		Toothpaste fluoride concentration (mg/kg)	
Age/gender	AI‡	UL‡	F+	F–	F+	F–	400	1,000
6-12-month-old infant	0.5	0.9	0.71	0.18			0.14	0.35
1-3-year-old toddler	0.7	1.3	0.57	0.25			0.12	0.30
5-6-year-old child	1	2.2	0.86	0.36	0.84 (1.74)	0.38 (0.73)	0.12	0.30
7-10-year-old child	1-2	2.2-10			0.99 (1.80)	0.45 (0.82)	0.3	
11-14-year old male	2-3	10	1.00	0.50	1.26 (2.34)	0.61 (1.09)	0.3	
11-14-year-old female	2-3	10	0.90	0.43	1.03 (2.09)	0.49 (1.00)	0.3	
15-18-year-old male	3	10			1.89 (3.53)	0.86 (1.88)	0.2	
15-18-year-old female	3	10			1.68 (3.27)	0.73 (1.41)	0.2	
19-24-year-old male	4	10	1.37	0.80	2.25 (4.28)	0.98 (2.09)	0.1	
19-24-year-old female	3	10			2.03 (4.03)	0.88 (1.87)	0.1	
25+-year-old male	4	10	2.10	1.12	2.50 (4.60)	1.26 (2.52)	0.1	
25+-year-old female	3	10	2.07	0.98	2.35 (4.52)	1.04 (2.16)	0.1	

* 95th percentile intakes are only available from the dietary modeling approach.
† Assumption: children up to 6 years receive a smear of toothpaste (2), weighing 0.22 g (27); children under 1 year retain 80 percent of toothpaste (17), while those aged 1-6 years retain 68 percent (18); all other intake estimates were taken from a US summary (19); all estimates based on two applications of toothpaste per day at a concentration of 1,000 mg F/kg, unless otherwise stated.
‡ Reference (7).
F+ = based on a water fluoride content of 1.0 mg/L.
F– = based on a water fluoride content of 0.1 mg/L.
AI, adequate intake; UL, upper level of intake.

defined by age and gender (Table 1). Weighted arithmetic mean intake values were calculated and 95th percentile intake values were taken from the ordered list of all intake estimates. The weightings are used to adjust the demographic profile of the survey population to that of the New Zealand population (10,14). A 95th percentile consumer is often used to represent a "high" or "extreme" consumer.

Food contributions

The contribution of a particular food to total dietary fluoride intake was calculated from NNS97 or CNS02 data by summing the contributions to fluoride intake from the specific food, across all consumers in a particular age-gender group, and dividing by the total fluoride intake for that age group. Foods were grouped into the food groupings used for the NZTDS. The total diet approach also allows the contribution of individual foods and groups of foods to total dietary intake to be determined (13).

High fluoride diets

For the identified age groups within the NNS97 and CNS02 data sets, individuals with the highest dietary intakes of fluoride were identified. Males and females were considered together for each age group and the 95th percentile level of fluoride intake was used to define high fluoride diets. The average amounts of individual foods consumed by this subset were identified and compared with the average of the whole age group.

Estimates of fluoride intake due to toothpaste use

Rates of actual toothpaste use for New Zealand children are not available. Infant and child (0-10 years) intakes of fluoride from toothpaste were estimated for two toothpaste fluoride concentrations – 400 and 1,000 mg/kg. While the higher fluoride concentration toothpaste is recommended in New Zealand (2), lower concentration toothpaste may be considered for use by children under 6 years in areas with a fluoridated water supply who are at low risk of dental caries (2). The Ministry of Health recommends that children under the age of 6 years use a smear of toothpaste (16), with mean values for this measure of 0.22 g being taken from the scientific literature (17). It was assumed that infants under the age of 12 months ingested 80 percent of the dispensed toothpaste (17) and children aged 1-6 years retained in the mouth or swallowed 68 percent of the dispensed toothpaste (18). While the study that derived this percentage only covered children up to 3.5 years, no information was found on toothpaste retention by children up to 6 years of age and this figure was used to cover the complete age range. Frequency of tooth brushing was assumed to be twice daily, as per the Ministry of Health's recommendation (16).

For all other age groups estimates of fluoride intake from toothpaste were taken from a recent US publication (19). Where there was overlap between the age ranges used in the current study and those in the US reference, a conservative approach was taken with the higher of the two possible estimates of fluoride intake being applied.

Risk characterization

The Nutrient Reference Values for Australia and New Zealand (7) give two reference levels of intake – adequate intake (AI) and upper level of intake (UL). The AI is a level that is assumed to be adequate, based on observations or experimentally determined estimates in apparently healthy people. The UL is the highest average intake likely to pose no adverse health effects to almost all individuals in the general population. As intake increases above the UL, the potential risk of adverse effects increases. The values of the AI and UL for various age groups are included in Table 1. Intakes for each age group were compared with these reference levels to assess potential public health risks.

Results

Dietary intake estimates

Table 1 summarizes estimates of dietary intake of fluoride for New Zealanders, based on total diet calculations and dietary modeling. There is generally good agreement between mean intake estimates between these two approaches, with estimates from the total diet approach within 20 percent of the estimates from dietary modeling. The exception to this is the total diet estimate for a young male (19-24 years) consuming fluoridated water, which is about half of the corresponding dietary modeling estimate. This appears to be due to the modest intakes of tea and coffee included in the total diet-simulated diets (about 20 percent of consumption levels for an adult male).

All mean and 95th percentile estimates of dietary fluoride intake are within the ULs defined for the respective age groups, irrespective of the approach (total diet or dietary modeling) used and the assumed fluoridation status of the water. However, in most cases, the mean dietary intake of fluoride does not meet the AI, even under scenarios of optimal water fluoridation. Although not presented here, the 99th percentile estimate of dietary fluoride intake for a 5-6 years child is at the UL, while for all older age–sex groups the 99th percentile intakes lie between the AI and the UL.

Impact of additional fluoride intake from toothpaste

Estimates of additional fluoride intake from toothpaste are included in Table 1. When considering the potential for combined intake of fluoride from the diet and fluoride-containing toothpastes, the population can be divided into three distinct groups. For infants (6-12 months, consuming a diversified diet compared with the first 6 months of mostly breast- and/or formula-feeding), a combination of a non-fluoridated water supply and additional fluoride from fluoride-containing toothpastes will result in mean estimates of fluoride intake close to the AI. The combination of a fluoridated water supply and low fluoride-containing toothpaste (400 ppm) will result in fluoride intake estimates below the UL, while combination with high fluoride-containing toothpaste (1,000 ppm) will result in fluoride intake estimates above the UL. For children aged 1-10 years, the combination of a fluoridated water supply and fluoride-containing toothpastes produces mean and 95th percentile estimates of fluoride intake that meet the AI without exceeding the UL.

For New Zealanders older than 10 years, the mean extra fluoride derived from toothpaste is generally insufficient to raise mean estimates of fluoride intake to above the AI level. Where 95th percentile estimates of dietary fluoride intake are available, from dietary modeling, combining mean intakes of fluoride from toothpaste with 95th percentile intakes of fluoride from the diet generally provides estimates of fluoride intake that meet the AI, but do not approach the UL.

Foods contributing to dietary intake

Table 2 summarizes the contribution of major food groupings to estimated dietary fluoride intake, while Table 3 lists foods that constitute major contributors to dietary fluoride intake.

In general, beverages are an important source of dietary fluoride across all age groups. For adults, alcoholic beverages are a relatively more important contributor for males than females, while the converse is true for non-alcoholic beverages. Animal products (meat, fish, chicken, and eggs) and grain products are consistent contributors (greater than 5 and 10 percent of the fluoride from a non-fluoridated diet, respectively) to dietary fluoride intake across all age groups and genders, although the proportional contribution of these food types tends to decrease with age.

For diets not including a fluoridated water supply, the importance of bread as a contributor to total fluoride intake reaches a peak during the 5-14 years age range. Carbonated beverages contribute most significantly to fluoride intake during the period 15-24 years, while the contribution of tea consumption to fluoride intake increases with age.

Table 2 Contribution of food groups to estimated mean dietary fluoride intake for various New Zealand age-gender groups (percent of total intake), fluoridated water supply (1.0 mg F/L)/non-fluoridated water supply (0.1 mg/L)

Food groups*	6 months infant†	1-3 years toddler†	5-6 years child†	7-10 years child‡	11-14 years female†	11-14 years male†	15-18 years female‡	15-18 years male‡	19-24 years female‡	19-24 years male†	25+ years female†	25+ years male†
Alcoholic beverages	0.0/0.0	0.0/0.0	0.0/0.0	0.0/0.0	0.0/0.0	0.0/0.0	0.8/1.9	2.1/4.2	2.1/5.0	6.4/11.0	0.8/1.6	4.5/8.5
Non-alcoholic beverages	27.5/11.5	59.4/19.3	65.1/26.3	59.5/29.6	59.8/25.5	56.9/23.9	72.4/46.9	63.8/37.5	76.3/53.1	58.2/36.5	82.9/68.8	73.1/56.1
Animal products	2.4/7.2	4.2/9.3	4.1/9.1	7.2/14.0	5.2/10.2	6.5/12.2	4.2/9.0	6.5/12.0	4.0/8.2	5.8/9.0	3.0/5.7	4.4/7.5
Dairy products	3.8/12.2	7.9/18.2	3.4/8.1	2.5/5.4	3.0/6.3	3.0/5.9	1.5/3.5	1.9/3.9	1.2/2.9	2.1/3.7	1.1/2.4	1.4/2.6
Fruit	2.0/6.4	4.4/10.1	3.1/7.4	1.5/3.3	3.0/6.3	2.0/4.0	0.7/1.6	0.7/1.5	0.6/1.5	2.8/4.7	1.2/2.6	1.2/2.3
Grain products	7.0/17.5	15.6/28.0	17.7/33.6	23.0/37.6	19.3/31.4	21.3/33.6	16.3/28.1	20.6/32.1	11.8/21.2	14.2/17.3	7.4/11.4	10.2/13.6
Infant formula and infant foods	54.4/35.7	2.9/2.1	0.0/0.0	0.0/0.0	0.0/0.0	0.0/0.0	0.0/0.0	0.0/0.0	0.0/0.0	0.0/0.0	0.0/0.0	0.0/0.0
Nuts	0.0/0.0	0.0/0.1	0.1/0.2	0.0/0.1	0.1/0.2	0.1/0.2	0.1/0.1	0.0/0.1	0.0/0.1	0.1/0.1	0.0/0.1	0.0/0.1
Oils and fats	0.0/0.1	0.0/0.1	0.1/0.1	0.0/0.0	0.1/0.2	0.1/0.2	0.1/0.2	0.1/0.2	0.1/0.1	0.1/0.2	0.0/0.1	0.1/0.1
Spreads and confectionery	0.8/2.5	1.1/2.6	1.3/3.1	1.2/2.4	1.5/3.1	1.7/3.4	0.8/1.8	0.7/1.4	0.5/1.3	1.0/1.8	0.6/1.2	0.71.3
Takeaway foods	0.9/3.0	2.2/5.1	2.4/5.6	NA	4.1/8.6	4.3/8.4	NA	NA	NA	5.8/9.9	1.0/2.1	1.7/3.1
Vegetables	1.2/3.9	2.2/5.1	2.7/6.5	4.1/7.7	4.0/8.3	4.1/8.2	3.1/6.8	3.6/7.1	3.4/6.8	3.4/5.7	2.0/4.2	2.6/4.9

* Alcoholic beverages: beer and wine; non-alcoholic beverage: tea, coffee, water, soft drinks, fruit drinks; animal products: meat, fish, shellfish, chicken, eggs; dairy products: milk, cheese, butter, ice cream, cream yoghurt, cream, dairy desserts; fruit: fresh fruits, dried fruits, canned fruits, fruit juices; grain products: bread, biscuits, breakfast cereals, bakery products, pasta, rice; infant formula and infant foods; infant formula from powder, weaning foods (cereal, savory or fruit-based); nuts: peanuts and peanut butter; oils and fats: margarine, oil, salad dressing; spreads and confectionery: chocolate, confectionery, honey, jam, snack bars, sugar, yeast extract; takeaway foods: hamburger, meat pie, pizza, hot potato chips, fried chicken, battered fish, Chinese meal; vegetables: fresh vegetables, canned vegetables.

† From total diet approach.

‡ From dietary modeling approach.

NA, not applicable, data from the 1997 National Nutrition Survey and 2002 National Children's Nutrition Survey do not allow identification of the source of food consumed.

Table 3 Contribution of key foods to estimated dietary fluoride intake for various New Zealand age-gender groups (percent of total intake)

Age	Main foods contributing to estimated dietary fluoride intake	
	F+	F–
6-12-month-old infant*	Infant formula (50%), water (22%), infant foods (5%), fruit drink (4%)	Infant formula (25%), infant foods (11%), yoghurt (8%), water (7%), bread (7%)
1-3-year-old toddler*	Water (44%), fruit drink (11%), bread (4.5%)	Water (10%), bread (10%), yoghurt (7%), biscuits (6%), fruit drink (5%), milk (4%), dairy dessert (4%)
5-6-year-old child*	Water (43%), fruit drink (10%), bread (8%), chocolate beverage (7%), tea (3%)	Bread (20%), water (10%), potatoes (5%), fruit drink (5%), tea (5%), biscuits (4%), carbonated beverage (4%)
7-10-year-old child†	Water (41%), bread (7%), tea (5%), carbonated beverage (4%), fruit drink (4%)	Bread (15%), water (9%), carbonated beverage (9%), tea (6%)
11-14-year-old male*	Water (35%), bread (10%), chocolate beverage (7%), fruit drink (7%), tea (4%)	Bread (20%), potatoes (7%), water (7%), carbonated beverage (6%), biscuits (4%), tea (4%)
11-14-year-old female*	Water (39%), bread (8%), chocolate beverage (7%), fruit drink (6%), tea (4%)	Bread (17%), water (8%), potatoes (6%), carbonated beverage (6%), tea (5%), biscuits (4%)
15-18-year-old male†	Water (38%), bread (8%), tea (8%), fruit drink (7%), carbonated beverage (7%)	Bread (17%), carbonated beverage (14%), tea (9%), water (8%), potatoes (5%)
15-18-year-old female†	Water (42%), tea (13%), carbonated beverage (6%), bread (6%), fruit drink (5%)	Tea (16%), bread (14%), carbonated beverage (13%), water (10%)
19-24-year-old male*	Water (15%), tea (12%), coffee, instant (10%), fruit drink (9%), carbonated beverage (7%), beer (6%), bread (5%)	Tea (11%), carbonated beverage (11%), beer (10%), bread (9%), caffeinated beverage (5%), potatoes (5%)
19-24-year-old female†	Water (43%), tea (21%), bread (5%), carbonated beverage (4%)	Tea (28%), bread (13%), water (10%), carbonated beverage (9%)
25+-year-old male*	Tea (41%), coffee, instant (15%), water (10%), beer (4%), bread (4%)	Tea (43%), beer (8%), bread (8%), coffee, instant (4%), carbonated beverage (4%)
25+-year-old female*	Tea (46%), coffee, instant (17%), water (14%), bread (3%)	Tea, (55%), bread (6%), coffee, instant (5%)

* From total diet approach.
† From dietary modeling approach.
F+ = Diet based on drinking water fluoride concentration of 1.0 mg/L.
F– = Diet based on drinking water fluoride concentration of 0.1 mg/L.

High fluoride intake diets

Analysis of high fluoride diets was carried out based on individual 24-hour dietary recall records (10,14). These records were only available for the population aged 5 years and older.

Children 5-10 years

The high fluoride intake diets (greater than 95th percentile) for this age group were characterized by a high consumption of a wide range of foods when compared with diets with average levels of fluoride intake. It is likely that the elevated fluoride intakes observed for these individuals are due to these children being consumers of high volumes of food, rather than any particular pattern of consumption, although the high level of tea consumption (317 g/person/day compared with an average of 30 g/person/day overall) is worth noting. On average, those with high fluoride intakes had approximately 10 percent higher body weights (mean = 37 kg) than the overall age group (mean = 33 kg).

The survey design of the CNS02 overrepresented certain population groups and the 3,275 respondents were made up of Maori (37 percent), Pacific Islanders (32 percent) and New Zealand European and other (30 percent). Of the respondents with high dietary fluoride intakes, 56 percent were Pacific Islanders, 26 percent were Maori, and 18 percent were New Zealand Europeans or other. Approximately two-thirds of this group were classified as coming from low socioeconomic groups (20), compared with approximately 42 percent of the total survey group.

The UL was exceeded by less than 0.1 percent of CSN02 respondents aged 5-10 years, based on a non-fluoridated water supply, and by approximately 0.8 percent of respondents, based on the scenario of a fluoridated water supply, using dietary modeling. The contribution to fluoride intake from toothpaste at the highest rate modeled would not change the percentage exceeding the UL for a non-fluoridated water supply, but for a fluoridated water supply this percentage would increase to 1.9 percent of respondents.

Adolescents aged 11-14 years

The high-fluoride intake group in this age range was also characterized by having higher than average consumption of a wide range of foods and this group probably represents consumers of high volumes of food in general. Foods of particular note consumed in greater quantities by this group include tea (mean 241 g/day compared with 45 g/day for all 11-14-year-old respondents), soft drinks (475 g/day compared with 214 g/day), fruit flavored drinks (93 g/day compared with 42 g/day), potatoes (193 g/day compared with 108 g/day), and bread (373 g/day compared with 132 g/day). On average, those with high fluoride intakes had slightly higher body weights (mean = 61 kg) than the overall age group (mean = 59 kg).

The high-fluoride intake group is more likely to be Pacific Islander (42 percent compared with 35 percent) and classified in the lower socioeconomic strata (42 percent at decile 10 compared with 27 percent) (20) when compared with the composition of the 11-14-year survey group overall.

For this age group, none of the daily diet scenarios represented in the CNS02 resulted in an estimate of fluoride intake that exceeded the UL for either fluoridated or non-fluoridated water supplies.

Adolescents aged 15-18 years

High-fluoride intake diets were characterized by high consumption of tea (average of 539 g/day compared with an average of 92 g/day for this age group overall), soft drinks (556 g/day compared with 304 g/day), milk (487 g/day compared with 216 g/day), bread (930 g/day compared with 165 g/day), and beer (590 g/day compared with 80 g/day) when compared with the average food consumption for this age group. While milk generally has a low fluoride concentration, it is commonly consumed in tea and checking of individual records suggested that this was the reason for higher milk consumption in the high-fluoride intake group. On average, those with high fluoride intakes had only marginally higher body weights (mean = 69 kg) than the overall age group (mean = 68 kg). Both the high-fluoride intake group and the total respondent sample for this age group are dominated by New Zealand Europeans (69 percent and 63 percent, respectively). Due to the relatively small number of respondents in this age group (319), these comparisons should be viewed with caution.

For this age group none of the daily diet scenarios resulted in an estimate of fluoride intake that exceeded the UL for either fluoridated or non-fluoridated water supplies.

Young adults aged 19-24 years

The high-fluoride intake group was characterized by having higher consumption of a wide range of foods and this group probably represents consumers of high volumes of food in general. Foods of particular note included beer (1,106 g/day compared with an age group average of 198 g/day) and tea (792 g/day compared with an age group average of 162 g/day). The high-fluoride intake group consumed lower average amounts of water (482 g/day compared with an age group average of 904 g/day). On average, those with high fluoride intakes had only slightly higher body weights (mean = 71 kg) than the overall age group (mean = 69 kg).

The demographic composition of the high-fluoride intake group (64 percent New Zealand European) is very similar to that of the 19-24-year-old group in general (60 percent New Zealand European). Due to the relatively small number of respondents in this age group (480), these comparisons should be viewed with caution.

For this age group, none of the daily diet scenarios resulted in an estimate of fluoride intake that exceeded the UL for either fluoridated or non-fluoridated water supplies.

Adults aged 25 years and over

A comparison of high fluoride intake diets and average fluoride intake diets for adults, who are 25 years of age or older, mirrors the pattern seen for the 19-24-year age group. Those with high fluoride intake diets consumed greater amounts of staples, indicating that they are probably consumers of high volumes of food in general. However, the most striking differences were in consumption of tea (1,796 g/day compared with an age group average of 454 g/day) and beer (655 g/day compared with an age group average of 167 g/day). On average, those with high fluoride intakes had only slightly higher body weights (mean = 74 kg) than the overall age group (mean = 73 kg).

The demographic profile of adults who have diets with high fluoride intakes is very similar to the adult profile in general. However, New Zealand Maori are over- represented (20 percent of high fluoride consumers compared with 10 percent in the NNS97 dataset overall), as are individuals classified in lower socio-economic groups (20) (44 percent compared with 33 percent in the dataset overall).

None of the adult daily dietary fluoride intake scenarios exceeded the UL when calculated on the basis of non-fluoridated water. When fluoridated water was assumed, only 0.1 percent of adult daily diets exceed the UL of 10 mg/day.

Discussion

With the exception of infants 6-12 months, all population groups mean dietary fluoride intake estimates were below the AI level for caries protection, irrespective of water fluoride status, and in most cases the additional fluoride contribution from toothpaste would be insufficient to bring the total fluoride intake above the AI. For 6-12 month infants a diet including fluoridated water results in mean dietary fluoride intake estimates above the AI, while the additional fluoride intake from high-fluoride toothpaste (1,000 ppm fluoride) would be sufficient for mean intakes to exceed the UL.

Mean levels of dietary fluoride intake generally increased with increasing age and were consistent with similar recent estimates made overseas(19,21), with estimated dietary intakes from areas with non-fluoridated water rising from approximately 0.2 mg/day in the first year of life to approximately 1 mg/day in adulthood. Access to a fluoridated water supply increases fluoride intake to 2-3 times the intake under conditions of a non-fluoridated water supply. This is not surprising, as the average fluoride levels of most foods fall within a fairly narrow range of concentrations, with most foods typically having fluoride contents in the range 0.1-1.0 mg/kg. Overall, intake of fluoride will be driven by consumption of dietary staples (bread, potatoes), beverages (particularly tea, soft drinks, and beer), and the fluoride status of local drinking water. For infants receiving infant formula, drinking water will also be a major source of dietary fluoride, as only powdered infant formulae are generally available in New Zealand.

Diets of individuals with the highest intakes of fluoride were characterized by high levels of food consumption, but notably high consumption of tea, across all age groups, and beer, within the adult groups. Comparison of body weights between the high-fluoride intake group and the overall survey population for the same age range demonstrated slightly higher body weights in the high fluoride groups, although these differences decreased with increasing age. While individual diet scenarios occasionally exceeded the UL, it should be stressed that the scenarios are based on an individual's recall of their diet in a single 24-hour period and may not represent habitual patterns of food consumption. The variability in long term fluoride intake is likely to be less than the variability observed for a single day (22) and the probability of individuals consistently exceeding the UL over a long period will be correspondingly lower than the estimates made in this study.

The estimates of dietary fluoride intake made in the current study were based on the best available New Zealand food consumption and food fluoride concentration data. However, as with any data, these data have limitations that may impact on the intake estimates derived. Specifically:

The age of fluoride concentration data and food consumption data

Food concentration data used in this study date from 1987-1988 and 1990-1991, while food consumption data for adults dates from 1997. The New Zealand food supply has become increasingly internationalized and diversified in the intervening years. It is uncertain what impact these changes may have had on the fluoride content of the food supply, although the similarity of fluoride concentrations in comparable foods from different countries (5,6,11,12) suggests the impact of these changes may be minimal.

Use of single day 24HDR food consumption information

While mean intakes generated from these food consumption data are likely to be valid, single day dietary recall records overstate the variability in habitual intake within a population (22). Consequently, 95th percentile dietary intakes reported in the current study may be overestimates of long term usual 95th percentile dietary fluoride intakes, although the fact that dietary intake of fluoride is driven by consumption of staples and common beverages suggests the degree of overestimation may be minor.

Under-reporting of food consumption

It has long been recognized that respondents will tend to underestimate or under-report serving sizes in dietary recall studies (23). This has the potential to result in underestimation of mean and percentile dietary intakes. An analysis of the NNS97 concluded that 12 percent of men and 21 percent of women were "definite under-reporters" (energy intake less than 90 percent of resting metabolic rate) (24).

Mapping

Foods analyzed in the NZTDSs were mapped to a wider range of foods, described in the CNS02 and NNS97. It is assumed that the mapped foods will have similar patterns of fluoride content to the analyzed foods. International data were consulted to confirm the validity of mapping, where possible.

Lack of food consumption information for the New Zealand population less than five years of age

The national nutrition surveys carried out in 1997 and 2002 only provide 24HDR records for the population five years and older and the current study used simulated diets for 6-12 month old infants and 1-3 year old toddlers, developed as part of the 2003/04 NZTDS (13). The diet for 6-12 month olds included powdered infant formula as the primary liquid food (350 ml/day), while the toddler diet included only minor consumption of formula (14 ml/day).

Fluoride concentration of drinking water in fluoridated supplies

While the fluoride concentrations of fluoridated supplies are monitored to ensure compliance with the New Zealand Drinking Water Standards, the data for individual supplies have not been aggregated into a national dataset. In this report, as a conservative approach, fluoride intakes have been modeled using the maximum recommended fluoride concentration value of 1.0 mg/L. However, actual water supplies will have a range of fluoride concentrations impacting on the fluoride intake of the population serviced by the water supply.

Conclusion

The assessment of the contribution of toothpaste to fluoride intake included in this study was based largely on international data sources and it is unknown whether these observations are representative of actual practices in New Zealand. In addition, the analysis included no consideration of variability in the fluoride intake from toothpaste, but this is potentially large. Some studies have concluded that dentifrice use may contribute over 50 percent of child fluoride intake, even in areas of optimal water fluoridation (25,26).

Given these limitations in the current study, it appears unlikely that significant numbers of New Zealanders will have intakes of fluoride above the UL for fluoride and the risk of dental fluorosis in the general population will be low. This conclusion is consistent with the results of studies that have found that, while mild and very mild dental fluorosis is not uncommon in New Zealand children, more serious dental fluorosis is rarely seen (21). The observation that the majority of the general population are unlikely to be achieving sufficient fluoride intake to achieve optimum caries protection may be a topic for further investigation.

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