Comparison of the Mineral Content of Tap Water and Bottled Waters

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OBJECTIVES: **Because of growing concern that constituents of drinking water may have adverse health effects, consumption of tap water in North America has decreased and consumption of bottled water has increased. Our objectives were to 1) determine whether North American tap water contains clinically important levels of calcium (Ca^{2+}), magnesium (Mg^{2+}), and sodium (Na^{+}) and 2) determine whether differences in mineral content of tap water and commercially available bottled waters are clinically important.**

DESIGN: **We obtained mineral analysis reports from municipal water authorities of 21 major North American cities. Mineral content of tap water was compared with published data regarding commercially available bottled waters and with dietary reference intakes (DRIs).**

MEASUREMENTS AND MAIN RESULTS: **Mineral levels varied among tap water sources in North America and among bottled waters. European bottled waters generally contained higher mineral levels than North American tap water sources and North American bottled waters. For half of the tap water sources we examined, adults may fulfill between 8% and 16% of their Ca^{2+} DRI and between 6% and 31% of their Mg^{2+} DRI by drinking 2 liters per day. One liter of most moderate mineralization European bottled waters contained between 20% and 58% of the Ca^{2+} DRI and between 16% and 41% of the Mg^{2+} DRI in adults. High mineralization bottled waters often contained up to half of the maximum recommended daily intake of Na^{+}.**

CONCLUSION: **Drinking water sources available to North Americans may contain high levels of Ca^{2+}, Mg^{2+}, and Na^{+} and may provide clinically important portions of the recommended dietary intake of these minerals. Physicians should encourage patients to check the mineral content of their drinking water, whether tap or bottled, and choose water most appropriate for their needs.**

KEY WORDS: **tap water; bottled water; calcium; magnesium; sodium.**
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Certain constituents of drinking water may have adverse health effects. Epidemiological studies have examined the relation between exposure to trace elements (e.g., copper, zinc, arsenic) and minerals (e.g., magnesium) and the occurrence of disease, including reproductive outcomes,[1] certain forms of cancer,[2] rare congenital malformations of the central nervous system,[3–6] cardiovascular disease,[7–11] and sudden death.[12–13] Because waterborne minerals are in ionic form and are easily absorbed by the gastrointestinal tract, it has been suggested that drinking water may be an important source of mineral intake.[14–16] In this study, we examined calcium (Ca^{2+}), magnesium (Mg^{2+}), and sodium (Na^{+}) levels because these minerals may be abundant in drinking water. In addition, Ca^{2+}, Mg^{2+}, and Na^{+} have important physiological functions, and an unsuitable intake of these minerals may increase the likelihood of disease.

Calcium intake is important at all ages,[17–18] but the need for Ca^{2+} is higher during childhood, fetal growth, pregnancy, and lactation.[19] Epidemiological, animal, and clinical studies support the existence of an inverse relation between Ca^{2+} intake and the occurrence of osteoporosis.[20–21] A diet that is fortified in Ca^{2+} may reduce the rate of age-related bone loss and hip fractures, especially among adult women.[22] In spite of this knowledge, nutritional surveys indicate that more than 50% of North Americans consume inadequate levels of Ca^{2+} and, on average, adult women consume only 60% of the required daily Ca^{2+} intake.[23] Although many foods are now fortified with calcium (e.g., orange juice), naturally bioavailable Ca^{2+} is found almost exclusively in milk, milk products, and water. Drinking water may be a significant source of Ca^{2+}, and Ca^{2+}-rich mineral water may provide over one-third of the recommended dietary intake of this mineral in adults.[15]

Epidemiological studies suggest that an inverse relation exists between Mg^{2+} intake and the occurrence of ischemic heart disease, cardiac arrhythmias, and sudden death.[12–13] Studies also suggest that an inverse relation exists between Mg^{2+} levels in drinking water and the occurrence of cardiac disease.[24] Nonetheless, a majority of the U.S. population consumes less than the daily Mg^{2+} requirement, and many individuals ingest less than 80% of the recommended level.[24] The major portion of Mg^{2+} intake is via food[25] such as nuts, green leafy vegetables, cereals, and seafood.[19] However, Mg^{2+} in water is highly bioavailable, and waterborne Mg^{2+} is absorbed approximately 30% faster and better than Mg^{2+} from food.[26–27] Consequently, Mg^{2+} supplementation may be best achieved using a high Mg^{2+} nutrient with the best bioavailability such as drinking water.[28]

Unlike the low Ca^{2+} and Mg^{2+} intakes in the North American diet, Na^{+} intake generally surpasses the recommended limits and has been estimated to be in the range of 4,000 to 6,000 mg per day.[23] Numerous studies have

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shown that a high Na^+ intake is associated with the occurrence of hypertension[20,22,29–32] and that dietary Na^+ restriction, achieved by not adding salt and avoiding Na^+-rich foods, may effectively reduce blood pressure.[19] Cheese, bread, cereals, and processed and preserved foods have a high Na^+ content.[23,33] However, drinking certain waters may unnecessarily increase Na^+ intake to a level that may be detrimental for health, especially for individuals on a Na^+-restricted diet.

Over the past decade, consumption of tap water in North America has declined as sales of commercially available bottled waters have risen. One in 5 North American households now uses bottled drinking water and, in the United States, annual per capita consumption of bottled water increased from less than 8 gallons in 1991 to almost 11 gallons in 1996.[34–35] Because drinking water may be an important source of mineral intake, the shift in consumption from tap water to bottled water may have important implications for health and disease. Thus, the objectives of this study were 1) to determine whether North American tap water contains clinically important levels of Ca^{2+}, Mg^{2+}, and Na^+, and 2) to determine whether differences in the mineral content of tap water and commercially available bottled waters are clinically important.

METHODS

Tap Water

We contacted the municipal water authorities of the 25 most populous cities in North America to obtain mineral analysis reports. We requested information regarding levels of Ca^{2+}, Mg^{2+}, and Na^+ for all of the water sources in each of these municipalities. In each case, we obtained mineral analysis reports for finished drinking water, i.e., water that is ready to be distributed through the tap water delivery system. Nineteen of the 25 cities provided us with mineral analysis reports for water samples collected between 1994 and 1997. Two additional cities provided us with reports for water samples collected between 1988 and 1991. The remaining 4 cities (Dallas, Tex; Jacksonville, Fla; San Antonio, Tex; and San Francisco, Calif) could not provide Ca^{2+}, Mg^{2+}, and Na^+ data for each of their tap water sources. Most municipalities provided analyses summarizing data collected during a 12-month period, three provided summaries for samples collected during a single month (Baltimore, Md; Chicago, Ill; and Milwaukee, Wis), and the city of Seattle, Wash, provided a summary for samples collected during a single day. Based on 1996 estimates, the populations in the twenty-one participating cities represent approximately 10% of the total North American population.[36]

Our data included mineral analysis reports of tap water originating from watersheds such as lakes, rivers, and streams (surface water) or from wells (groundwater). According to U.S. Environmental Protection Agency (EPA) regulations, the treatment of surface water must include coagulation, filtration, and disinfection procedures. In contrast, groundwater receives natural treatment by traveling through the soil and does not usually require any additional processing, with the exception of disinfection.[37] Because of the inherent differences between the two water types, we grouped tap water sources according to surface water or groundwater.

The EPA imposes stringent water treatment regulations under the authority of the Safe Drinking Water Act. The Act was established to protect the quality of drinking water and focuses on all waters actually or potentially designed for drinking use. In addition to maximum contaminant levels, EPA regulations include standard methods for the examination of water as well as analytical methods for compliance determinations of chemical and microbiological contaminants in drinking water. Primary maximum contaminant levels (MCLs) have been set to regulate the levels of arsenic, cyanide, mercury, chromium, and other chemicals associated with risks for public health. Secondary maximum contaminant levels (SMCLs) have also been set to regulate the aesthetics of tap water and relate to factors such as alkalinity, temperature, odor, color, pH, and water hardness. Importantly, owners or operators of public water systems are obligated to attain primary standards set by the EPA but are only encouraged to attain secondary standards. Levels of Ca^{2+}, Mg^{2+}, and Na^+ are included in the SMCL category because their levels in tap water are not currently associated with risks for public health.

Bottled Waters

We obtained Ca^{2+}, Mg^{2+}, and Na^+ levels for 37 commercially available North American bottled waters from a previous study and from published data regarding bottled waters.[19,38–39] Mineral levels for commercially available European bottled waters were obtained from a single source, *The Good Water Guide*, detailing the geographical source, history, and market share of 250 bottled waters in 42 countries.[39] In our study, we included the 73 European waters for which Ca^{2+}, Mg^{2+}, and Na^+ levels were available in this publication.

Significant differences exist between North American and European standards regulating the bottled water industry. For example, the sale of distilled water (i.e., water that is deficient of all dissolved substances) is permitted according to the United States Bottled Water Regulations.[40] In contrast, the European Economic Community Mineral Water Regulations prohibit the processing and treatment of any water bottled from a source.[38] The Food and Drug Administration requires that "mineral waters" contain between 500 and 1,500 mg/L of total dissolved solids, a combination of the dissolved minerals.[38] In Europe, however, water with any level of mineralization is considered "mineral water."

In our analyses we grouped bottled waters according to their level of mineralization. North American bottled waters were grouped into spring waters or mineral waters, according to their label. Because all European bottled waters are labeled "mineral waters," they were grouped into low, moderate, or high mineralization waters. Precise definitions of mineralization levels vary from country to country.[39] For the purpose of this study, low mineralization indicates less than 200 mg/L of Ca^{2+}, Mg^{2+}, and Na^{+}, moderate mineralization indicates between 200 and 700 mg/L of these minerals, and high mineralization indicates more than 700 mg/L.

Dietary Reference Intakes

Over the past five decades, nutritional experts have established recommended dietary allowances (RDAs) for various minerals and nutrients. Recently, a cooperative effort between the United States and Canada revised previous recommendations and created dietary reference intakes (DRIs).[41] Compared to the old RDAs, the new DRIs incorporate the concept of preventing nutrient deficiencies as well as risk reduction for chronic conditions such as heart disease, diabetes, hypertension, and osteoporosis. In our analyses, we compared mineral levels in tap and bottled waters to DRIs in order to examine the clinical significance of mineral intake from drinking water.

The DRI of Ca^{2+} is highest for adolescents (1,300 mg) and for the elderly (1,200 mg). Adult men and women 19 to 50 years of age require 1,000 mg of Ca^{2+} per day. A 250 ml glass of milk typically contains 300 mg of Ca^{2+}, one cup of cottage cheese contains approximately 100 mg of Ca^{2+}, and two tablespoons of cream cheese contain approximately 30 mg.[42] For Mg^{2+}, the DRI has been set at 6 mg/kg/day in industrialized countries.[28] A 70-kg North American male, for instance, requires 420 mg of Mg^{2+} daily. Dietary reference intakes of Mg^{2+} are generally higher for males than for females but also depend on age. A 30-g serving of almonds or half a cup of spinach contain approximately 80 mg of Mg^{2+}, and one third of a cup of bran cereal contains approximately 50 mg.[42] Currently established DRIs do not yet include estimates for Na^{+}. Previously established RDA estimates, however, indicate that healthy adults require at least 500 mg of Na^{+} per day,[43] and nutritional experts have set a maximum recommended intake of 2,400 to 3,000 mg of Na^{+} per day.[23] A hamburger typically contains more than 500 mg of Na^{+}, 1 cup of macaroni and cheese contains more than 700 mg of Na^{+}, and 2 slices of pizza may contain more than 1,000 mg.[42]

Published data on water consumption are limited, and the few available studies have reported an important variability in tap water intakes in North America.[14] The amount of water consumed daily varies from individual to individual and largely depends on other sources of fluids.[11] Nutritional experts have recommended that consumption of 30 ml/kg/day of water is sufficient for the elderly and that a provision of 150 ml/kg/day is recommended for infants.[45] To examine the clinical significance of mineral intake from drinking water, we made assumptions regarding the consumption of tap water and bottled water in North America. We assumed that adults drink 2 liters of tap water per day, equivalent to eight 250 ml glasses. Because bottled water is more expensive and less readily available than tap water, we also assumed that adults only drink 1 liter of bottled water per day, equivalent to approximately three (commonly sold) 355 ml bottles. In Table 1, we provide the gender and age-specific DRIs of Ca^{2+} and Mg^{2+}. The reader may therefore compare recommended intakes with actual intakes according to varying quantities and sources of water.

Statistical Analysis

Levels of Ca^{2+}, Mg^{2+}, and Na^{+} varied within each type of tap or bottled water in our study. In addition, sample sizes were small for groundwater sources ($n = 8$), for North American mineral waters ($n = 9$), and for high mineralization European bottled waters ($n = 7$). Mean levels can be skewed by extreme values in small samples. Consequently, we report the mean, standard deviation, median, and range of Ca^{2+}, Mg^{2+}, and Na^{+} levels for the different tap and bottled waters in our study. We also report correlation coefficients (r) to examine the association between Ca^{2+}, Mg^{2+}, and Na^{+} levels within the same type of drinking water.

RESULTS

North American Tap Water

Important variations exist in the mineral content of tap water among the North American cities investigated (Tables 1 and 2). In general, levels of Ca^{2+}, Mg^{2+}, and Na^{+} were higher among groundwater sources than among surface water sources (Table 2). Tap water sources that contained high levels of Ca^{2+} generally contained high levels of Mg^{2+} ($r = 0.86$) but not necessarily high levels of Na^{+} ($r = 0.36$). Of the twelve states and three provinces in our study, mineral levels were highest in Arizona, California, Indiana, and Texas. Variations were also found in mineral content of different water sources within the same North American city. Calcium levels, for example, varied from 9 to 60 mg/L among the three water sources in San Jose. In Los Angeles, Mg^{2+} levels varied from 5 to 29 mg/L (4 sources), and in Columbus, Na^{+} levels varied from 10 to 51 mg/L (2 sources). Variations therefore exist in the levels of Ca^{2+}, Mg^{2+}, and Na^{+} among the tap water sources of North American cities and even among different water sources within the same city.

When compared to the recommended daily intakes of Ca^{2+}, Mg^{2+}, and Na^{+}, mineral intake from tap water is generally low but may be important when drinking from mineral-rich sources. For half of the tap water sources, adults may fulfill between 8% and 16% of their Ca^{2+} DRI by drinking 2 liters per day. Similarly, in every other water source, adult men may fulfill between 6% and 23% of their

Table 1. Mineral Content of North American Tap Water, North American Bottled Waters, and European Bottled Waters (mg/L)

	Ca^{2+}	Mg^{2+}		Na^{+}
	Males and Females	Males	Females*	Males and Females
Dietary reference intake, mg/day				
1 – 3 years	500	80	80	Maximum
4 – 8 years	800	130	130	recommended
9 – 18 years	1300	240–410	240–360	intake of
19 – 50 years	1000	400–420	310–320	2,400 to 3,000 mg
>50 years	1200	420	320	per day
North American tap water				
Surface water sources (n = 36)				
Mean ± SD	34 ± 21	10 ± 8		35 ± 41
Median	36	8		18
Range	2 – 83	0 – 29		0 – 169
Ground water sources (n = 8)				
Mean ± SD	52 ± 24	20 ± 13		91 ± 67
Median	48	12		83
Range	26 – 85	2 – 48		8 – 195
North American bottled waters				
Spring Waters (n = 28)				
Mean ± SD	18 ± 22	8 ± 18		4 ± 4
Median	6	3		4
Range	0 – 76	0 – 95		0 – 15
Mineral Waters (n = 9)				
Mean ± SD	100 ± 125	24 ± 42		371 ± 335
Median	8	7		240
Range	3 – 310	1 – 130		36 – 1,095
European bottled waters				
Low mineralization waters (n = 40)				
Mean ± SD	60 ± 40	16 ± 19		13 ± 13
Median	54	14		9
Range	4 – 145	1 – 110		1 – 56
Moderate mineralization waters (n = 26)				
Mean ± SD	262 ± 139	64 ± 37		157 ± 197
Median	217	56		49
Range	78 – 575	9 – 128		2 – 660
High mineralization waters (n = 7)				
Mean ± SD	60 ± 59	16 ± 20		1,151 ± 153
Median	33	9		1,133
Range	5 – 176	4 – 60		900 – 1,419

* *For pregnant women add 40 mg of Mg^{2+} per day.*

Mg^{2+} DRI, and adult women may fulfill between 8% and 31% of their Mg^{2+} DRI by drinking 2 liters per day. In most tap water sources, however, 2 liters contain less than 5% of the maximum recommended daily intake of Na^{+}. Thus, in some North American cities, drinking 2 liters of tap water per day from mineral-rich tap water sources may fulfill clinically significant portions of the Ca^{2+} and Mg^{2+} DRIs in adult men and women.

Commercially Available Bottled Waters

Mineral levels varied among commercially available North American and European bottled waters (Tables 1, 3, and 4). North American spring waters contained very low mineral levels. North American mineral waters generally contained high levels of Na^{+} and some contained important levels of Ca^{2+} and Mg^{2+}. The only strong correlation found was between Ca^{2+} and Mg^{2+} levels in mineral waters (r = 0.71). Among European bottled waters, moderate mineralization waters contained the highest levels of Ca^{2+} and Mg^{2+}, and high mineralization waters contained the highest levels of Na^{+} (Tables 1 and 4). Among moderate mineralization waters, higher Ca^{2+} levels corresponded to lower Na^{+} levels (r = −0.61), and among high mineralization waters, higher Na^{+} levels corresponded to lower levels of Ca^{2+} (r = −0.75) and Mg^{2+} (r = −0.76).

When compared to the recommended intakes of Ca^{2+}, Mg^{2+}, and Na^{+}, mineral intake from bottled water depends on the type of water that is being consumed. Adults fulfill very little (<3%) of their DRIs when drinking most spring waters. Drinking North American mineral waters, however, may fulfill an important proportion of the Ca^{2+} and Mg^{2+} DRIs as well as the maximum recommended intake for Na^{+}. For instance, one liter of Mendocino mineral water contains more than 30% of the Ca^{2+} and Mg^{2+} DRIs in adult women, and 1 liter of Vichy Springs contains more than one third of the maximum recommended Na^{+} intake. On the other hand, drinking 1 liter of most moderate mineralization

Table 2. Mineral Content of Tap Water in Major North American Cities (mg/L)

City	Water Source	Ca^{2+}	Mg^{2+}	Na^{+}
Surface water				
Baltimore, Md	Montebello	21	6	11
	Ashburton	20	4	9
Boston, Mass	Winsor Dam	2	1	3
	Wachusett	4	1	7
	Norumbega	4	1	10
	Weston	4	1	12
	Spot Pond	5	1	16
Chicago, Ill	North	37	1	8
	South	36	12	7
Cincinnati, Ohio	Single source	38	6	17
Columbus, Ohio	Dublin Road	36	8	51
	Hap Cremean	27	10	10
Denver, Colo	Marston	31	7	18
	Foothills	28	7	21
	Moffat	18	3	8
Detroit, Mich	Moffat	26	7	5
El Paso, Tex	Central	43	15	132
	East	56	13	160
Houston, Tex*	Single source	21	2	38
Indianapolis, Ind	White River	83	28	47
	Fall Creek	64	25	20
	TW Moses	51	18	18
	White River North	78	29	41
Kansas, Mo	Single source	51	8	57
Los Angeles, Calif	Los Angeles Aqueduct	21	5	37
	River Conduit	58	13	48
	Jensen	39	16	57
	Weymouth	68	29	98
Milwaukee, Wis*	Weymouth	36	12	8
Montreal, Quebec	Single source	34	8	11
New York, NY	Catskill-Delaware	6	1	6
	Croton	21	4	18
Philadelphia, Pa	Baxter	28	5	14
	Queen Lane	39	13	33
	Belmont	42	12	24
Phoenix, Ariz	Croton	51	20	169
San Diego, Calif	Skinner, Winchester	66	27	92
San Jose, Calif	Santa Clara Valley	56	14	57
	Hetch Hetchy	9	3	9
Toronto, Ontario	Tolt	40	9	12
Vancouver, British Columbia	Single source	2	0	0
Ground water				
Columbus, Ohio	Parsons Ave.	32	10	62
El Paso, Tex	West	26	2	145
	Northeast	44	11	104
	East	52	12	195
	Airport	34	8	134
Indianapolis, Ind	Geist	83	26	8
	Harding	85	40	32
San Jose, Calif	Hetch Hetchy	60	48	48

Data were collected between 1994 and 1997.
* *Indicates that samples were collected between 1988 and 1991.*

European waters may help North Americans fulfill between 20% and 58% of their Ca^{2+} DRI and between 16% and 41% of their Mg^{2+} DRI. High mineralization European waters are rich in Na^{2+} and 1 liter may contain up to 47% of the maximum recommended daily intake of this mineral. Thus, Ca^{2+}, Mg^{2+}, and Na^{+} intake from selected commercially available bottled waters may be appreciably higher than from most tap water sources, even when drinking only 1 liter of bottled water per day.

DISCUSSION

Mineral levels of tap water vary among North American cities and even among different water sources within the

Table 3. Mineral Content of Selected Commercially Available North American Bottled Waters (mg/L)

	Ca^{2+}	Mg^{2+}	Na^{+}		Ca^{2+}	Mg^{2+}	Na^{+}
Spring waters				Poland Spring, Me	0	2	3
Adobe Springs, Calif	3	96	5	Pure Hawaiian, Hawaii	0	0	0
Alhambra, Calif	1	1	4	Pure Spring Water, Ga	49	4	0
Arrowhead, Calif	20	5	3	Sierra, Calif	0	0	0
Black Mountain, Calif	25	1	8	Sparkletts, Calif	5	5	15
Caddo Valley, Ark	36	3	2	Talawanda Spring, Ohio	0	0	3
Canadian Spring, Canada	11	3	2	Talking Rain, Wash	2	2	0
Carolina Mountain, NC	6	0	5	Utopia, Tex	76	17	8
Clairval, Canada	20	7	13	Zephyrhills, Fla	52	7	4
Cobb Mountain, Calif	5	2	4				
Crystal Geyser Alpine, Calif	0	6	13	Mineral waters			
Deer Park, Me	1	1	1	A Santé, Calif	4	1	160
Georgia Mountain Water, Ga	2	0	0	Calistoga, Calif	7	1	150
Great Bear, NY	1	1	3	Canada Geese, Canada	282	10	36
Hawaiian Springs, Hawaii	6	3	6	Crystal Geyser, Calif	8	3	160
La Croix, Wis	37	22	4	Lithia Springs, Ga	120	7	680
Mount Olympus, Utah	8	2	3	Mendocino, Calif	310	130	240
Mountain Valley, Ark	68	8	3	Montclair, Canada	8	12	475
Naya, Canada	38	20	6	Montellier, Canada	3	3	340
Ozarka, Tex	18	1	5	Vichy Springs, Calif	157	48	1,095

Source: von Wiesenberger A. The Pocket Guide to Bottled Water. 1st ed. Chicago: Contemporary Books; 1991.

same city. Variations in mineral levels also exist among commercially available bottled waters. North American tap water and North American bottled waters generally contain low mineral levels. European bottled waters contain higher mineral levels than North American tap and bottled waters. Calcium and Mg^{2+} levels are highest among moderate mineralization European waters and Na^{+} levels are highest among high mineralization European waters.

Mineral intake from drinking water depends on the individual and on the source and quantity of the water that is being consumed. Adults who drink 2 liters of tap water that contains at least 50 mg/L of Ca^{2+} and 16 mg/L of Mg^{2+} may fulfill more than 10% of the DRIs of these minerals. This is the case for most individuals in Indianapolis, Ind; Los Angeles, Calif; San Jose, Calif; and Phoenix, Ariz; where tap water sources are generally rich in minerals. Because of their lower intake requirements, children may fulfill an important portion of their DRIs by drinking tap water. Toddlers in certain North American regions may fulfill 17% of their Ca^{2+} DRI and 50% of their Mg^{2+} DRI by drinking 4 glasses (1 L) of tap water per day.

Mineral intake from spring waters is minimal, and only some North American mineral waters contain high Ca^{2+} and Mg^{2+} levels. Drinking selected European waters may nonetheless fulfill an important portion of the Ca^{2+} and Mg^{2+} DRIs. Bottled waters such as Evian and Perrier (France) are labeled "mineral waters" but contain low mineralization levels. Mineral waters that contain moderate mineralization levels (e.g., Aproz, Contrex, Vittel Hépar), however, may best fulfill the DRIs of Ca^{2+} and Mg^{2+}. Adult women may fulfill more than 20% of their Ca^{+} DRI and more than 17% of the Mg^{2+} DRI when drinking 1 liter of such bottled waters. In contrast, high mineralization bottled waters contain little Ca^{2+} and Mg^{2+} but up to 100% of the maximum recommended Na^{+} intake. The American Heart Association has recommended that drinking water contain a maximum of 20 mg/L of Na^{+} for individuals on a severely restricted Na^{+} diet (500 mg of Na^{+} per day).[14] One liter of high mineralization North American or European waters may contain up to three times this maximum level.

The results of our study have several implications for the consumption of water in North America. Because of the variations in the mineral content of tap water in North American cities, North Americans do not equally consume Ca^{2+}, Mg^{2+}, and Na^{+} when drinking the same quantity of tap water. Sodium levels are generally low in tap water, but dietary intake of Ca^{2+} and Mg^{2+} can be supplemented by drinking at least 2 liters per day from mineral-rich tap water sources. This may be especially true for children and for individuals with poor dietary habits.

If North Americans prefer to drink commercially available bottled waters, they should be selective when deciding which water to drink. Individuals should choose to drink bottled water with an optimal mineral profile, i.e., high levels of Ca^{2+} and Mg^{2+} and little Na^{+}. However, few of the bottled waters we examined have an optimal mineral profile. North Americans may also be more likely to drink mineral-deficient bottled water, such as spring waters, rather than mineral-rich bottled water. This is because mineral-rich bottled water is generally associated with an unfavorable taste. In addition, most European bottled waters are more expensive than North American waters, and many are not available to consumers in North America.

Several potential limitations of our study should be mentioned. First, although we examined the mineral content of tap water in 21 major North American cities, these cities represent only 10% of the North American

Table 4. Mineral Content of Selected Commercially Available European Bottled Waters (mg/L)

	Ca^{2+}	Mg^{2+}	Na^{+}
Low mineral content*			
Abbey Well, United Kingdom	54	36	45
Acqua di Nepi, Italy	72	26	32
Acqua Fabia, Italy	124	5	15
Acqua Panna, Italy	15	5	3
Aqua-Pura, England	53	7	27
Ballygowan, Ireland	114	16	15
Boario, Italy	124	41	6
Brecon Carreg, United Kingdom	48	17	6
Bru, Belgium	23	23	10
Buxton, United Kingdom	55	19	24
Chiltern Hills, England	114	1	8
Claudia, Italy	104	22	56
Cristalp, Switzerland	115	40	20
Crodo Lisiel, Italy	60	2	6
Evian, France	78	24	5
Fiuggi, Italy	15	5	6
Font Vella, Spain	26	5	12
Fonter, Spain	35	7	11
Glenpatrick Spring, Ireland	112	15	12
Henniez, Switzerland	111	19	9
Hella, Germany	51	4	8
Highland Spring, United Kingdom	39	15	9
Levissima, Italy	18	1	1
Naleczowianka, Poland	119	24	21
Perrier, France	145	4	14
San Benedetto, Italy	43	25	8
San Bernardo, Italy	12	1	1
Spa Reine, Belgium	4	1	3
St. Michaelis, Germany	43	4	21
Strathmore, United Kingdom	60	15	46
Tipperary, Ireland	37	23	25
Thorspring, Iceland	6	1	8
Valvert, Belgium	68	2	2
Vera, Italy	34	13	2
Vichy Nouvelle, Finland	70	110	1
Viladrau, Spain	16	2	9
Vittel Bonne Source, France	91	20	7
Volvic, France	10	6	9
Voslauer, Austria	57	37	5
Moderate mineral content†			
Apollinaris, Germany	89	104	425
Aproz, Switzerland	454	67	8
Badoit, France	200	100	160
Contrex, France	467	84	7
Crodo Valle d'Oro, Italy	510	51	2
Fachingen, Germany	113	62	500
Ferrarelle, Italy	408	23	50
Franken Brunnen, Germany	198	42	52
Gerolsteiner, Germany	364	113	129
Hassia Sprudel, Germany	176	36	232
Vittel Hépar, France	575	118	13
Passugger, Switzerland	286	24	46
Pedras Salgadas, Portugal	132	9	550
Peterstaler, Germany	216	49	215
Pracastello, Italy	164	46	28
Robacher, Germany	256	128	40
Rippoldsauer, Germany	248	37	150
Robacher, Germany	256	128	40
Romerquelle, Austria	146	65	13
Radenska, Slovenia	217	97	470
Salus Vidago, Spain	78	10	660
San Pellegrino, Italy	204	57	47
Sangemini, Italy	322	19	21
Valser, Switzerland	436	54	11
Vichy Original, Finland	100	110	220
Vittel Grande Source, France	202	36	3
High mineral content‡			
Kaiser Friedrich, Germany	5	4	1,419
Krystynka, Poland	176	60	900
SaintYorre, France	30	7	1,108
San Narciso, Spain	53	9	1,120
Uberkinger, Germany	26	17	1,180
Vichy Celestins, France	100	9	1,200
Vichy Catalan, Spain	33	8	1,133

* *Low mineral content: less than 200 mg/L of* Ca^{2+}, Mg^{2+}, Na^{+}.
† *Moderate mineral content: between 200 and 750 mg/L of* Ca^{2+}, Mg^{2+}, Na^{+}.
‡ *High mineral content: more than 750 mg/L of* Ca^{2+}, Mg^{2+}, Na^{+}.
Source: Green M, Green T. The Good Water Guide. London, England: Rosendale Press; 1994.

population. The variation in the mineral content among all North American tap water sources may therefore be even greater than in our study. Second, the levels of Ca^{2+}, Mg^{2+}, and Na^{+} in tap water were obtained from municipal analysis reports, and levels of Ca^{2+}, Mg^{2+}, and Na^{+} in bottled waters were obtained from published data. Examining tap and bottled water samples in a single laboratory would have provided more reliable results. Finally, our study only examined levels of Ca^{2+}, Mg^{2+}, and Na^{+} in tap and bottled water. Drinking water may contain several other minerals (e.g., fluoride, potassium, zinc) and trace elements (e.g., arsenic, cyanide, lead) that are associated with benefits and risks for public health.[2–11,27,44] Aesthetic factors such as taste, color, and temperature may also be important to consider when choosing drinking water.

The average North American consumes insufficient quantities of Ca^{2+} and Mg^{2+} and too much Na^{+}. Recommended dietary intakes of Ca^{2+} and Mg^{2+} are best fulfilled via the consumption of foods in which these minerals are abundant and bioavailable. The results of our study suggest that drinking water may be an important dietary source of Ca^{2+}, Mg^{2+}, and Na^{+}. This is because minerals are highly bioavailable in water and because drinking water sources available to North Americans may contain clinically important levels of these minerals. Adequate daily consumption of some tap and bottled waters may help North American children and adults supplement dietary intake of Ca^{2+} and Mg^{2+} as well as reduce Na^{+} intake. Physicians should therefore encourage their patients to check the mineral content of their drinking water, whether tap or bottled, and to choose the water that is most appropriate for their individual dietary needs.

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