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invited review

"Drink at least eight glasses of water a day." Really? Is there scientific evidence for "8 × 8"?

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Heinz Valtin. "Drink at least eight glasses of water a day." Really? Is there scientific evidence for "8 × 8"? *Am J Physiol Regul Integr Comp Physiol* 283: R993–R1004, 2002. First published August 8, 2002; 10.1152/ajpregu.00365.2002.—Despite the seemingly ubiquitous admonition to "drink at least eight 8-oz glasses of water a day" (with an accompanying reminder that beverages containing caffeine and alcohol do not count), rigorous proof for this counsel appears to be lacking. This review sought to find the origin of this advice (called "8 × 8" for short) and to examine the scientific evidence, if any, that might support it. The search included not only electronic modes but also a cursory examination of the older literature that is not covered in electronic databases and, most importantly and fruitfully, extensive consultation with several nutritionists who specialize in the field of thirst and drinking fluids. No scientific studies were found in support of 8 × 8. Rather, surveys of food and fluid intake on thousands of adults of both genders, analyses of which have been published in peer-reviewed journals, strongly suggest that such large amounts are not needed because the surveyed persons were presumably healthy and certainly not overtly ill. This conclusion is supported by published studies showing that caffeinated drinks (and, to a lesser extent, mild alcoholic beverages like beer in moderation) may indeed be counted toward the daily total, as well as by the large body of published experiments that attest to the precision and effectiveness of the osmoregulatory system for maintaining water balance. It is to be emphasized that the conclusion is limited to *healthy* adults in a *temperate* climate leading a largely *sedentary* existence, precisely the population and conditions that the "at least" in 8 × 8 refers to. Equally to be emphasized, lest the message of this review be misconstrued, is the fact (based on published evidence) that large intakes of fluid, equal to and greater than 8 × 8, are advisable for the treatment or prevention of some diseases and certainly are called for under special circumstances, such as vigorous work and exercise, especially in hot climates. Since it is difficult or impossible to prove a negative—in this instance, the absence of scientific literature supporting the 8 × 8 recommendation—the author invites communications from readers who are aware of pertinent publications.

fluid intake; optimal fluid intake; daily water intake; water balance

WE SEE THE EXHORTATION EVERYWHERE: "drink at least eight glasses of water a day" (17). The advice comes not only (as in the above quote) from a respected health columnist of *The New York Times*, but also from numerous writers in the popular press (3, 6, 10, 26, 54). Some, perhaps many, physicians counsel their patients in a similar vein, both orally and in writing. So prevalent is the recommendation that it is now commonly expressed simply as "8 × 8" (signifying that each of the 8 glasses in question must have a volume of 8 oz).

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As we look around us in our daily activities, we can observe how slavishly the exhortation is being followed. Everywhere, people are carrying bottles of water and taking frequent sips from them. Prior to September 11, when there was little restriction on how much baggage passengers could carry onboard airplanes, it was common to see young professionals loaded down with luggage—garment bags, carry-ons, computers, pocketbooks—while simultaneously juggling a cell phone in one hand and a bottle of water in the other. The practice continues today, although the passengers may perforce be less encumbered with luggage. It is perfectly acceptable to sip water anywhere, as during lectures, seminars, and conferences. A colleague has told me he estimates that something like 75% of his students carry bottles of water and sip from them as they attend lectures; indeed, a pamphlet distributed at the University of California Los Angeles counsels its students to "carry a water bottle with you. Drink often while sitting in class. . ." (3). I have seen a professional concert pianist walk onstage carrying a glass of water, and a well-known columnist bring his own bottle of water to his interview on a nationally televised talk show. For some, the bottle has even become a security blanket: recently, as I listened to a postdoctoral fellow presenting a seminar, I observed that whenever his flow of words stopped momentarily, while he contemplated the next sentence, he would, seemingly unconsciously, pick up a bottle of water from the table, unscrew its top, and replace it, without ever taking a sip.

This review deals with the origin of our new national habit of 8 × 8. How did it start? Is there any scientific evidence that supports the recommendation? Does the habit promote good health? Might it be harmful?

EQUIVALENT VOLUMES

As one reads the literature, one finds water or fluid intake expressed in different units: ounces (oz); pints (pt); quarts (qt); gallons, US or Imperial (gal); grams (g), liters (l); milliliters (ml); others. Equivalent volumes for these units are given in Table 1.

To facilitate comparisons among various recommendations, I shall use the metric volumes of liters and milliliters throughout, and, where I quote recommendations in other units, I shall indicate the metric equivalent in parentheses.

Table 1. *Equivalent volumes for units used in designating water and fluid intake*

Unit	Abbreviation	Equivalent Volume oz	cups	ml*
Cup	c	8		237
Ounce (fluid)	oz		1/8	30
8 × 8 ounces			**8**	**1,893**
Pint	pt	16	2	473
Quart	qt	32	4	946
Gallon, US	gal	128	16	3,785
Gallon, Imperial	gal	152	19	4,546
Gram	g			~1
Liter	l	34	4.2	1,000

*ml, Rounded to nearest ml.

For the purposes of this paper, the equivalents to bear in mind are that *eight 8-oz glasses equal 1,893 ml, or 2 qt, or ½ gal (US), or roughly 1.9 liters.*

WHAT, WHERE, FOR WHOM?

The recommendation that we drink at least eight glasses of water a day is subject to a broad range of interpretation. Does it refer to tap water and bottled water only, or are we talking about "fluid," with its contained electrolytes and other solutes? Is the recommendation restricted to temperate climates? Is it restricted to sedentary persons or does it include "normally active" individuals, meaning adults who work in offices and engage in mild exercise?

The following quote may reflect what most authors who write on the subject have in mind: "According to most authorities, a sedentary person should drink at least eight glasses of water (~8 oz each) per day. That totals a whopping one-half gallon of water for the average couch potato" (42). The second sentence makes clear that by "sedentary" the writer is thinking of persons who are physically inactive and almost certainly overweight. His use of the word "water," plus the fact that elsewhere in the article he specifically excludes caffeinated drinks from the daily allotment [a common misperception (40)] , leaves little doubt that he means water per se. This, then, is the very minimum that 8 × 8 means to convey.

My view is not so restricted. The concept I have in mind is *daily intake of drinking fluid* (as distinct from fluid in solid food) meaning *all drinking fluids*, including tap water and bottled water, coffee, tea, soft drinks, milk, juices, and possibly even beer in moderation (see Table 52, p. 92, of Ref. 29); and I am referring to *healthy adults* in a *temperate climate* who may indulge in mild exercise, such as walking.

POSSIBLE ORIGIN OF 8 × 8

Despite a comprehensive search of the literature (see SEARCH STRATEGY, end of article), I have not been able to find an article where 8 × 8 is recommended on the basis of solid scientific evidence. The closest reference was an obituary on the renowned nutritionist Fredrick J. Stare, brought to my attention by Dr. Barbara Rolls, an expert on the topic of thirst (76). The obituary (77) stated, in part, that Dr. Stare "was an early champion of drinking at least six glasses of water a day." A former colleague of Dr. Stare, Dr. Elizabeth Whelan (82), found the following passage in a book that Dr. Stare coauthored with Dr. Margaret McWilliams in 1974 (81):

> How much water each day? This is usually well regulated by various physiological mechanisms, but for the average adult, somewhere around 6 to 8 glasses per 24 hours and this can be in the form of coffee, tea, milk, soft drinks, beer, etc. Fruits and vegetables are also good sources of water.

The passage, which is not referenced, appears as part of a very brief section at the very end of the book, after the authors have discussed various aspects of nutrition (calories, carbohydrates, fats, proteins, vitamins, etc.) in the preceding 174 pages. Thus water is taken up in this book almost as an afterthought.

Nevertheless, given Dr. Stare's leading position in the field of nutrition, it is conceivable that 8 × 8 began with this apparently offhand comment. If that is correct, however, it is astonishing that not one of the numerous sources I have read cited Dr. Stare's work, nor were a half dozen leading nutritionists who work in this field able to point me to the passage. (Dr. Whelan found it only when she began searching after reading the obituary of Dr. Stare.)

Furthermore, lest the advocates of 8 × 8 now adopt this quote from Dr. Stare as scientific evidence, let me point out the following: *1*) this is an apparently casual opinion by Drs. Stare and McWilliams, which is undocumented by any scientific experiment; *2*) there is a huge difference between "somewhere around 6 to 8 glasses" and "at least eight glasses" (17), and it is the latter recommendation that is in question; *3*) in Drs. Stare and McWilliams's passage, caffeinated and alcoholic drinks such as coffee, tea, soft drinks, and beer are allowed, whereas these categories are excluded by the proponents of 8 × 8; and *4*) Drs. Stare and McWilliams introduce their estimate with the statement that water intake is "usually well regulated by various physiological mechanisms," whereas the advocates of 8 × 8 claim that if we wait for these mechanisms to determine our water intake we will already be dehydrated.

According to J. Papai (65), P. Thomas has suggested a different origin for 8 × 8. Thomas reminds us that in 1945 the Food and Nutrition Board of the National Research Council wrote (31):

> A suitable allowance of water for adults is 2.5 liters daily in most instances. An ordinary standard for diverse persons is 1 milliliter for each calorie of food. Most of this quantity is contained in prepared foods.

Thomas suggests that the last sentence was not heeded, and the recommendation was therefore erroneously interpreted as eight glasses of water to be *drunk* each day. The Food and Nutrition Board is currently reevaluating its recommendation [see below, under *National Academy of Sciences (USA), Food and Nutrition Board*].

CUSTOMARY DAILY FLUID INTAKE

How much were average American adults drinking before 8 × 8 was popularized and how much are they drinking today? Has there been an increase in fluid intake since 8 × 8 became popular? Is it possible that we are already ingesting eight 8-ounce glasses of water or fluid a day?

Before 8 × 8

A very thorough study on water intake was published by Ershow and Cantor (29), who analyzed data collected during the Nationwide Food Consumption Survey of 1977–78 (89). The survey, conducted by the US Department of Agriculture, gathered voluminous information on total water and tap water intakes of some 26,081 persons, of all ages, living throughout the continental United States. The results that seem most relevant to the above questions come from Tables 47 and 52 of the Ershow and Cantor report (29) and they are shown in the second column of Table 2: adults of both genders, 20–64 years of age, from all regions of the continental United States, during all seasons, consumed 674 g (ml) of drinking water and 1,022 g (ml) of other beverages per day.

The average total intake of drinking fluid of these persons was thus 1,696 ml/day, which at first glance does not seem far removed from the 8 × 8 recommendation of ~1,900 ml/day (Table 1). However, a breakdown of the beverages shows that nearly one-half (47%) of the total drinking fluid was coffee (396 ml), tea (152 ml), soft drinks (179 ml), and alcohol (70 ml), i.e., presumably mostly caffeinated and alcoholic drinks that we are admonished, by proponents of the 8 × 8 rule, to subtract from total daily drinking fluid because they are said to have diuretic effects (3, 10, 17, 26, 42, 47, 54, 59).

Recent experiments of Grandjean and colleagues (40) cast serious doubt on the often asserted diuretic role of caffeinated drinks, except, possibly, in persons who have not ingested caffeine for nearly a week (60, 84). Grandjean et al. examined the possible influence of equal volumes of various combinations of beverages on the state of hydration as judged by changes in body weight and standard urinary and plasma variables, such as osmolality and concentrations of electrolytes and creatinine. The subjects were 18 healthy adult males aged 24–39 years, and the drinks included water only, as well as caffeinated and noncaffeinated caloric and noncaloric beverages. (The effects of alcohol were not tested in the Grandjean study.) There were no significant effects on any of the variables by which

Table 2. *Comparison of daily fluid intake by American adults of both genders before and after 8 × 8*

Beverage	Before 8 × 8 1977–78	After 8 × 8 1994–96, 1998
Water	674	841
Coffee	396	378
Tea	152	171
Soft drinks	179	371
Alcohol	70	139
Milk and milk drinks	165	142
Juices	60	146
Total (ml)	1,696	2,188

Values are in ml. Because the categorization of beverages was not identical in the 2 surveys (29, 90), several of the amounts listed represent best estimates. Before values are from Ershow and Cantor (29; Table 52, p. 92.) After values are from US Department of Agriculture, 2000 (90).

hydration was judged.[1] The authors concluded that "advising people to disregard caffeinated beverages as part of the daily fluid intake is not substantiated by the results" of their study (40).

Nevertheless, the public perception of the 8 × 8 rule continues to be that caffeinated and alcoholic drinks do not count toward the total daily intake. If we apply this rule to the data in the second column of Table 2, subtracting 797 ml (coffee, tea, soft drinks, and alcoholic drinks) from 1,696 ml, then, assuming that most of the coffee, tea, and soft drinks contained caffeine, the estimated total drinking fluid intake of 899 ml falls ~1 liter short of the 8 × 8 recommendation.

Since 8 × 8

The United States Department of Agriculture conducted another extensive survey of food and water intake during the three years, 1994 through 1996, plus 1998 (90). This survey, known as the *Continuing Survey of Food Intakes by Individuals* (CSFII), sampled more than 15,000 persons in 50 states plus the District of Columbia (90).

One analysis of the data from CSFII was published in April 2000 under the title *Estimated Per Capita Water Ingestion in the United States* (44). This analysis was conducted by the Drinking Water Intake Subcommittee of the Environmental Protection Agency's (EPA) Office of Water, and it was oriented, not surprisingly, given the EPA's sponsorship, toward possible pollutants. The analysis differs from that of Ershow and Cantor (29) in two important respects: *1*) it includes water used in the preparation of foods and beverages, not only in the home setting (as did the analysis of Ershow and Cantor) but also in restaurants and school cafeterias and *2*) it excludes milk, milk products, soft drinks, beer, and other alcoholic beverages. Unfortunately, therefore, it is very difficult or impossible to glean data from the EPA analysis that could be compared with the 1,696 ml of "average total intake of drinking fluid" of the Ershow and Cantor report (second column of Table 2).

The original report of the 1994–96, 1998 survey (90), however, does provide data that allow a comparison (Table 2, third column), which reveals the following main points: *1*) an increase of ~25% in the consumption of water; *2*) roughly a doubling of soft drinks and alcoholic beverages (see, also, Ref. 41); and *3*) a nearly 2.5-fold increase in juices. As a result of these increases, coupled with only minor changes in the other beverages, the mid 1990s showed a rise in fluid intake from a value below 8 × 8 to one that is at or above 8 × 8.

Still, according to the proponents of 8 × 8, that is not enough, because, they say, caffeinated and alcoholic beverages do not count. To the extent that the coffee, tea, and soft drinks in the 1994–96, 1998 survey (third column of Table 2) contained caffeine, these beverages plus the alcohol constituted nearly one-half of the total fluid intake [roughly the same proportion as in the 1977–78 survey (29)].

Other Data Since 8 × 8

World Health Organization (WHO). In a summary extracted from *Guidelines of Drinking-Water Quality, 1996* (99), it is stated that in studies carried out in Canada, the Netherlands, the United Kingdom, and the United States, "the average daily *per capita* consumption was usually found to be less than 2 litres." This statement suggests that in these countries during the early to mid 1990s, people were drinking somewhat less than the 1.9 liters (Table 1) recommended by 8 × 8.

National Academy of Sciences (USA), Food and Nutrition Board. According to the office of the Director of the Food and Nutrition Board, a panel on electrolytes and water is beginning ". . .a study that will look at the potential daily requirements and tolerable upper intake levels for electrolytes and fluids." The target date for issuing the report is the middle of 2003. The Board does not currently recommend an amount for daily fluid intake.

Medical and graduate students. For many years while I was teaching renal physiology, we ran a laboratory exercise in which our students collected and analyzed their own 24-h urinary output. Year after year, the averaged results came out astonishingly close to the "normal" values published in the literature, which, I think, legitimizes the application of the student results to the present discussion. In 1994, the 24-h urinary volume for 69 students averaged 1,520 ± 100 ml (Table 3). (For the 4-year period, 1991 through 1994, the average for ~300 students was 1,685 ± 140 ml.) The validity of these values is corroborated by the fact that the 24-h excretion rates of sodium, potassium, nitrogen, osmoles, and creatinine for these collections all fell within the normal ranges.

If we apply the figure of 1,520 ml to commonly accepted "normal" values for water turnover (Table 3), i.e., fecal loss of 100 ml and insensible loss of 900 ml; water in food of 1,000 ml and metabolic water of 300 ml, then we can calculate an average drinking water intake for these 69 students of ~1,220 ml per person per day. This value is reasonably close to the 1,696 ml

Table 3. *Average daily balance for water in an adult human in a temperate climate, using the urinary output of medical and graduate students as determined in a teaching laboratory exercise*

	Input		Output		
Substance	Dietary	Metabolic	Urinary	Fecal	Insensible
Water					
as fluid	1,220*	300	1,520†	100	900
in food	1,000				
Total	2,520			2,520	

Values are in ml/day. Table adapted from Valtin and Schafer (92). *Calculated from total estimated output. †Mean of 24-h collections from 69 students.

[1] A minuscule, statistically insignificant loss of body weight (mean of 0.3%) occurred in *all* groups, including the control group that drank water only.

of total daily drinking fluid reported in the 1977–78 survey[2] (second column of Table 2), as is our estimate for total daily dietary water input of 2,220 ml (Table 3) compared with 2,243 ml in the 1977–78 survey (Table 52, p. 92, of Ref. 29).

Personal fluid intake. As I discussed the 8 × 8 rule with friends, relatives, and colleagues—and by the way, nearly everyone could quote the rule to me—the common response was, "I don't come close to drinking eight 8-ounce glasses a day." I therefore decided to measure my own customary daily intake of drinking fluid on 2 days ~2 mo apart. The results for the first day, shown in Table 4, reveal a total fluid intake of 1,440 ml. The total was less on the second day of testing (10/24/01), namely, 1,060 ml, and, of course, the total amount varies slightly from day to day.

In summary, then, the two major population-based surveys of 1977–78 and 1994–96, 1998 suggest that total fluid intake by American adults may have increased by approximately two glasses per day during the two decades that saw the introduction of 8 × 8 (Table 2). (Our own assessments suggest that some of us have not participated in this increase.) However, in view of the persistent admonition that caffeinated and alcoholic drinks do not count, the proponents of 8 × 8 continue to tell us that "Americans still do not drink enough water" (54).

Table 4. *Representative daily fluid intake by the author recorded on 8/29/01*

Breakfast	
coffee with milk	650
orange juice	175
Lunch	
cranberry juice	240
Dinner	
cocktail	125
water	250
Total fluid intake	1,440 ml

POSSIBLE BENEFITS OF A HIGH WATER INTAKE

Before we conclude that either the high water intake specified by 8 × 8 is not needed or that the high intake should, nevertheless, be recommended, we must examine the possible advantages and possible disadvantages of a high or low intake.

Rationale

The arguments for a high water intake in the lay press go something like this: our bodies consist mostly of water (50–70% of body weight; ~42 liters) and our blood, muscles, brain, and bone are made up mainly of water (~85%, 80%, 75%, and 25%, respectively). Therefore, *1*) we need water to function and survive and *2*) we need *at least* eight 8-ounce glasses of water each day. The second conclusion, in addition to being unproven, is a nonsequitur; it is akin to arguing that our homes run on electricity, and that, therefore, every house needs *at least* 1,000-ampere service.

Prevention of Cancer, Heart Disease, and Other Conditions

In a 10-year study involving nearly 48,000 men, Michaud and coworkers (57) found that the incidence of cancer of the urinary bladder was reduced significantly by a high fluid intake. The top 20% of subjects who participated in the study drank 2,531 ml per day or more, while the bottom 20% drank 1,290 ml or less; the authors calculated that within this range, the risk of bladder cancer decreased by 7% for every 240 ml (~1 cup or one 8-oz glass; Table 1) of fluid added. There was a significant decrease in risk even in men who drank only 1,440 ml (~6 glasses), i.e., well below the 8 × 8 recommendation. Not everyone, however, agrees with this benefit of a high fluid intake, especially in women (18, 37); also see discussion in Ref. 57.

A similar correlation has been reported for colorectal cancer and premalignant adenomatous polyps (53, 79, 86). Taking account of the many known risk factors for these tumors, these multivariate studies found significant, inverse correlations between the total intake of fluids, or specifically of water, and the risk of colorectal cancer as reflected in the incidence of adenomatous polyps. In some instances (79, 86), the beneficial effects were apparent with as little as five glasses of water a day. As with cancers of the urinary bladder, there may be gender-related differences.

Chan and associates (21) carefully analyzed the possible association between water intake and fatal coronary heart disease in 12,017 women and 8,280 men who participated in the prospective Adventist Health Study. They found, at a 6-year follow-up point, that women who drank five or more glasses of water per day (1,185 ml or more) reduced their risk of fatal coronary heart disease by ~41% compared with women who drank two glasses or less (474 ml or less). The comparable figure in men was 54% less risk. The effect was limited to water; in fact, the drinking of "fluids other than water" (coffee, tea, juices, soft drinks) appeared to *increase* the risk of fatal coronary heart disease.

In their very cautious analysis of these findings, the authors (21) point out: *1*) that the correlations are not necessarily causal (although they may involve the effect of hydration on hemorheological variables such as blood viscosity); *2*) that the findings might be unique to Seventh Day Adventists living in California, especially since they drink considerably more water and less caffeinated and alcoholic drinks than do other groups; *3*) that the trends in the risks are significant only in men, whereas in women the risk of fatal coronary heart disease was as low as or lower in those drinking three or four glasses of water a day (711 to 948 ml) as in those who drank five or more glasses; and *4*) that other

[2] If, instead of the assumed 1,000 ml for water in solid food (Table 3; see also, for example, Ref. 62), we substitute 545 ml [from Table 47, p. 87 of Ershow and Cantor (29); some experts now quote a value of 500–750 ml for water derived from solid food (49)], then the calculated "water as fluid" of 1,675 ml comes astonishingly close to the 1,696 figure reported by Ershow and Cantor (Table 2).

studies, likely ones with experimental design, will be needed to confirm the findings. In the context of this article, I would point out that the reference point of two glasses of water per day or less (474 ml or less) is considerably lower than what most people drink (see Table 2) and that three to four glasses a day, and certainly five glasses a day, may suffice to lower the risk.

As to prevention of other diseases, conditions of the urinary system, such as urinary tract infections (80) and urinary stones (14), mainly come to mind.

As reports on the possible benefits of fluid intake on the prevention of diseases increase, we must bear in mind both the amount of water that might be needed for this effect, as well as the suitability of this possible preventive measure for a given individual. With the recent elucidation of the human genome, it may not be appropriate to recommend a very high fluid intake *universally* (as do the proponents of 8 × 8), but rather to restrict the recommendation to those who are known to have a propensity for the disease(s) in question.

Other Claimed Benefits

Losing weight. There is some evidence, in both women (51) and men (75), that water drunk along with a meal or water incorporated into food (74, 85) does promote satiety. By and large, it is not yet clear to what extent this effect reduces food intake, how long the effect lasts, and how much fluid might be needed to influence satiety. In one study, Rolls and her colleagues (74) reported the intriguing finding that water incorporated into food, as in chicken soup, appears to be more effective as a "preload" in curtailing appetite during a subsequent meal than if the same amount of water was drunk during the preload alongside the same food, in this case chicken casserole. The intake of food ingredients and of water was identical in the experimental periods, only the mode of ingesting the water was different (74). An analysis by Stookey (85) supports this concept.

Constipation. The notion that a high fluid intake will facilitate bowel movements was tested by Chung et al. (24). They found, in 15 healthy adults of both genders, that although an extra intake of 1 or 2 liters of either Gatorade or plain water significantly increased urine flow, there was no discernable effect on the output of stool. The authors warn that their results were obtained in healthy adults who did not complain of constipation, and that, therefore, the possibility remains that a high fluid intake might help relieve constipation in those who have it (11). However, inasmuch as the intestines have a large capacity for absorbing extra ingested water (63), the efficacy of a high fluid intake in relieving constipation needs to be proven by well-controlled scientific experiments.

The list of advantages of a high fluid intake goes on. Benefits are claimed for fatigue, arthritis, lack of mental alertness, angina, migraine, hypertension, asthma, dry cough, dry skin, acne, nosebleed, depression (see, for example, Refs. 6, 10, 56). One amusing website where many of these claims are refuted is Snopes.com (58), although the authors rely mostly on quotes from scientists (albeit, very reputable ones) and newspapers rather than on scientific articles.

Speculative Advantages

Bankir and her group (15, 23) performed careful experiments, both in animals and humans and assembled supporting evidence from the literature that suggests that chronically high plasma vasopressin concentrations may have deleterious effects (the extrapolation being that a high fluid intake and consequent low vasopressin will prevent those effects). The primary findings are that *1*) sustained high concentrations of vasopressin increase glomerular filtration rate (GFR), probably through tubuloglomerular feedback (TGF) (15) and *2*) low urinary flow rates reduce sodium excretion (23), possibly through vasopressin-mediated upregulation of sodium channels (ENaC) (61) and Na-K-ATPase (28). The possible deleterious effects from these changes are *1*) hyperfiltration causing acceleration of chronic renal failure and *2*) increased sodium retention hastening the development of salt-sensitive hypertension, consequences that might be prevented by a high fluid intake. Of course, in the present article I am examining possible advantages of a high fluid intake in *healthy* individuals, not in persons with chronic renal failure or hypertension. Insofar, however, as a high fluid intake might influence the decrease in GFR that accompanies normal aging or *prevent* the development of hypertension, it seems fair to mention these two consequences at least as speculations.

POSSIBLE HAZARDS OF A HIGH WATER INTAKE

Thus far the evidence for forcing a high fluid intake on healthy adults in a temperate climate seems weak, at best. We may need further data, including genomic evidence for susceptibility, before recommending 8 × 8 universally even for the prevention of diseases, such as certain types of cancer or renal stones. But despite the dearth of compelling evidence for 8 × 8, many persons are likely to retort, "But what *harm* would it do?" The fact is that, potentially, there is harm even in water.

Water Intoxication

Even modest increases in fluid intake can result in severe water intoxication if the renal excretion of water is limited by a sustained influence of the antidiuretic hormone (ADH), either endogenous or exogenous, on the kidney. This serious eventuality occurred recently in a young woman with neurogenic (central or pituitary) diabetes insipidus (G. L. Robertson, personal communication). For many years she had been treated satisfactorily with DDAVP, a synthetic analog of the natural ADH arginine vasopressin. During this long period of treatment, she did not have any known episodes of hyponatremia or water intoxication because her water intake was regulated appropriately by the thirst mechanism. However, when she developed a minor upper respiratory infection and was advised to drink lots of fluids, her kidneys could not excrete sufficient quantities of urine because they were under the sustained antidiuretic influence of the DDAVP. Tragically, she rapidly developed severe water intoxication from which she died. Here, then, is a most unfortunate example of how a simple folk remedy that is usually innocuous, namely, to "force fluids" in treating flulike symptoms, could not be tolerated under special circumstances.

Citing this story as a potential hazard of 8 × 8 may seem like a weak argument because diabetes insipidus is a relatively rare disorder. However, the danger of water intoxication may not be all that uncommon, as is illustrated by the next story, which was reported on the PBS *NewsHour* on July 30, 2001 (16).

A fairly new recreational drug, especially among teenagers, is called Ecstasy. It is used extensively at dances, called "raves," but is now being taken in other settings as well. One striking side effect of Ecstasy is intense thirst, and this particular segment of *NewsHour* (16) reported the death of a 16-year-old girl who drank herself into fatal hyponatremia (water intoxication) after her first ingestion of Ecstasy. The many euphoric effects of Ecstasy (16) may have caused secretion of endogenous vasopressin, which prevented this girl from excreting the copious amounts of water she drank, for it is difficult or impossible for individuals to drink themselves into severe hyponatremia without a simultaneous, sustained antidiuretic influence on their kidneys (73).

A similarly sad story, also of a 16-year-old girl and also, apparently, a first-time taker of Ecstasy, was reported in *The New York Times* of February 12, 2002 (70). This young woman stopped breathing before she was taken to the hospital. Although her peers advised her to drink a lot of water and although she was said to have been very thirsty and to have drunk "enormous quantities of water," we cannot be certain that she died of hyponatremia, especially since she is said to have vomited much or most of the water that she drank. Be that as it may, Ecstasy is a dangerous drug, although most teenagers do not seem to know or accept that fact; some apparently ascribed this young woman's death to not having drunk enough water (70). Furthermore, the use of Ecstasy is increasing, as are the resulting visits to hospital emergency rooms, and the drug caused at least 15 deaths during the year 2000 (16).

Nonfatal Hyponatremia

The above and some other examples (35) are tragic incidents of fatal hyponatremia, which, we hope, will remain relatively rare. However, dilution of the plasma as reflected in mild, largely asymptomatic hyponatremia is said to be common in general practice (33). Moreover, nonfatal hyponatremia has been reported in a variety of circumstances (32, 48, 64). In the majority of patients, hyponatremia reflects an excess of water in the body rather than a decrease in sodium (91). Therefore, urging a high fluid intake on absolutely every person may well run the danger of inducing water intoxication and potentially serious sequelae (93), not only in the elderly (52, 66) but also in healthy young persons (63).

Exposure to Pollutants

The quality of the water we drink has become a worldwide issue. National (44) and international (99) organizations concern themselves with the problem; in fact, an electronic search of the literature with the code word "water" overwhelmingly identifies articles having to do with the quality of water rather than with its quantity. Largely because of the fear of pollutants in our tap water, but also because vigorous chemical treatment often imparts a bad taste to tap water, people are turning in droves to bottled water (34, 54, 83).

Sometimes, although probably not in the majority of instances, this choice might lead to the drinking of a poorer quality of water than would be the case with tap water. Jody Vilschick, the editor of *Endless Water*,[3] presented a concise review of the state of bottled water in the United States (95). She quotes authorities as stating that, although the majority of bottled water is pure, in some instances it may contain bacteria or carcinogens, and she offers some simple guidelines by which consumers might be able to tell the difference. In an effort to be fair, she lists websites for the participants in the dispute, the International Bottled Water Association (43) on one side and the Natural Resources Defense Council on the other.

But whether it is the tap water that is not pure or the bottled water, there can be no doubt that a high fluid intake will increase one's exposure to pollutants, especially if the high intake is sustained over years.

Inconvenience, Expense

In healthy individuals, the imbibing of large volumes of water (or of fluid, as in soft drinks) invariably leads to increased production of urine and more frequent urination. Although some dismiss this consequence as minor (17), for others it is a major inconvenience that sometimes causes embarrassment. And for those who satisfy the requirements of 8 × 8 with bottled water, the practice incurs a fairly large expenditure, costing far more than were the needs to be met with tap water (95).

MYTHS

In addition to the specific benefits discussed earlier, many lay writings on 8 × 8 make certain other claims, which are discredited by scientific evidence. A number of these myths have been discussed by Jaret (45); here are several more.

[3] Clarification for possible conflict of interest: *Endless Water* is the quarterly newsletter of the Diabetes Insipidus Foundation, Inc., of which I am Vice President.

Thirst Is Too Late

It is often stated in the lay press (17, 19, 22, 26) and even in professional journals (47) that by the time a person is thirsty that person is already dehydrated. In a number of scientific treatises on thirst, one finds no such assertion (1, 12, 30, 67, 69, 76, 98). On the contrary, a rise in plasma osmolality of less than 2% can elicit thirst, whereas most experts would define dehydration as beginning when a person has lost 3% or more of body weight (96), which translates into a rise in plasma osmolality of at least 5%. Another way of stating the same fact is that whereas the osmotic threshold for thirst is ~294 mosmol/kgH_2O[4] (Fig. 1) (72, 97), dehydration begins when the plasma osmolality has risen to ~302 mosmol/kgH_2O (basis for the calculations can be found in Ref. 92, Problem 2–3). Or, yet a third way of stating it: thirst sets in at a plasma osmolality that is still within the accepted normal range for this variable, namely, 280–296 mosmol/kgH_2O (50, 67, 87, 92).

Figure 1 makes another point: inasmuch as the threshold for release of vasopressin (284.7 mosmol/kgH_2O; also see Refs. 13, 97) is lower than that for thirst (293.5 mosmol/kgH_2O), moment-to-moment needs for water balance are met by changes in plasma vasopressin concentration and consequent changes in urine flow, whereas thirst and resultant intake of water are invoked at a later point (72). Osmotic regulation of vasopressin secretion and thirst is so sensitive, quick, and accurate (67) that it is hard to imagine that evolutionary development left us with a chronic water deficit that has to be compensated by forcing fluid intake.

Dark Urine Means Dehydration

Whether or not this statement is correct will depend on how dark the urine is, because the depth of color in urine will vary inversely with the urinary volume. Although the volume varies greatly among individuals, in our student laboratory (see above, under *Other Data Since "8 × 8"*) the mean value was 1,520 ml/24 h (Table 3), with a mean urine osmolality of 590 mosmol/kgH_2O. Both values are those generally cited as being "normal," namely, 1,500 ml/24 h and 600 mosmol/kgH_2O, respectively (73, 92). At a urine osmolality ~600 mosmol/kgH_2O, the concentration of solutes in the urine is such that the urine has a moderately yellow color, which might be interpreted as "dark," especially when contrasted against "pale yellow" or "clear," which is specified in most of the lay literature (26). Yet, at the above-cited normal urinary volume and osmolality, the plasma osmolality will be well within the normal range and nowhere near the values of 300 mosmol/kgH_2O and higher, which are seen in meaningful dehydration. Therefore, the warning that dark urine reflects dehydration is alarmist and false in most instances.

[4] As is emphasized in the legend for Fig. 1, the range for osmotic thresholds is wide (100), so that a single "normal" value cannot be quoted.

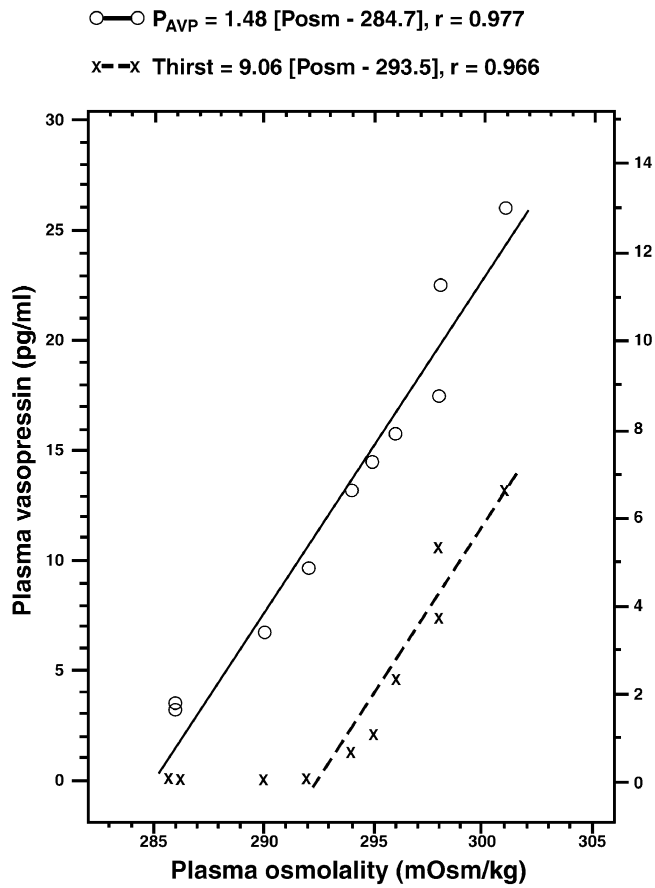

Fig. 1. Influence of plasma osmolality on the plasma vasopressin concentration (○) and on thirst (x) in a *single* healthy human subject. Calculated thresholds for this person are plasma osmolality of 284.7 mosmol/kgH_2O leading to a plasma vasopressin concentration of 1.48 pg/ml; and plasma osmolality of 293.5 mosmol/kgH_2O eliciting minimally detectable thirst. Note: threshold values and slopes vary greatly among healthy persons, although they are relatively constant in any 1 individual; these differences are, in part, genetically determined (100). [Reprinted by permission of Blackwell Scientific, Inc. (71).]

High Fluid Intake Maintains Glomerular Filtration Rate

This statement, when given in the context of 8 × 8, implies that fluid intakes lower than 8 × 8 diminish the glomerular filtration rate (GFR) (6). The opposite effects of the state of hydration on GFR were demonstrated recently in carefully controlled experiments on healthy young human subjects (2). Furthermore, years ago McCance and coworkers (55) showed that the GFR (as measured by the clearance of inulin) declines only during very severe dehydration, for example, when body weight declines by 5% or more (also see Ref. 36). Certainly, the acute water diuresis that follows the ingestion of 1 liter of water can be accounted for by an inhibition of vasopressin secretion and decreased tubular reabsorption of water, without a measurable change in GFR (92), or possibly even with a decrease in GFR (2).

Note that we already touched on this subject under *Speculative Advantages*, where Bankir and associates suggest that a sustained high plasma concentration of vasopressin (as can be expected during low fluid intake) will increase GFR (in agreement with the findings in Ref. 2) and that, therefore, a high fluid intake might have the beneficial influence of keeping GFR at the normal level.

CONCLUDING COMMENTS

In summary, this article is concerned with fluid intake for *healthy* adults in a *temperate* climate, performing, at most, *mild* exercise. Excluded were any special circumstances, such as illnesses, hot climates, and strenuous work or exercise.

Despite an extensive search of the literature and many personal inquiries and discussions with nutritionists and colleagues (see SEARCH STRATEGY, end of article), I have found no scientific reports concluding that we *all* must "drink at least eight glasses of water a day." On the contrary, there are publications that state the opposite (38, 46, 52), and skepticism about 8×8 has begun to appear in the lay press (5, 7–9, 20, 39, 58, 78, 88). Not only is there no scientific evidence that we need to drink that much, but the recommendation could be harmful, both in precipitating potentially dangerous hyponatremia and exposure to pollutants and also in making many people feel guilty for not drinking enough. The *Harvard Men's Health Watch* (5) aptly states, "It's getting to be quite a chore: tracking grams of fat and fiber, adding milligrams of sodium, counting calories, and now watching water."

Is there scientific documentation that we do *not* need to drink 8×8? There is highly suggestive evidence, although no proof. Two lines of evidence can be cited: *1*) the voluminous literature on the efficacy of the osmoregulatory system, which maintains water balance through vasopressin and thirst (71, 94, 98), and *2*) the fact that the mean daily fluid intake of thousands of presumably healthy humans (column 2 of Table 2, Tables 3 and 4) is less than the 1,900 ml prescribed by 8×8. Although it is a fair assumption that these healthy humans maintained a stable body weight, water balance, and plasma osmolality—important endpoints for determining "optimal fluid intake" (68)—I am not aware that these particular variables have been published in this context. Moreover, even though it can be argued that the subjects were healthy, the surveys do not address the question of whether the subjects were as healthy as they would have been had they drunk more fluid. A very systematic survey, possibly prospective and certainly incorporating the exacting standards of today's evidence-based medicine (21, 25, 27), would be needed to settle that point. By the time such a meticulous survey might show that the incidence or severity of certain diseases is reduced by drinking 8×8 or more, we may have genomic information that would limit the advice "to drink at least eight glasses" to only a portion of the population. Hence, I would argue that even if and when such proof is ultimately obtained, the universal application of 8×8 would not be justified. Finally, in view of the strong suggestive evidence cited above, I would argue further that for the time being the burden of proof that everyone needs 8×8 should fall on those who persist in advocating the high fluid intake without, apparently, citing any scientific support.

In contrast to the need for final proof in support of 8×8, there is now strong scientific evidence that not all of the prescribed fluid need be in the form of *water*. Through careful experiments that passed peer review, Grandjean and colleagues have shown that caffeinated drinks (coffee, tea, and soft drinks) should indeed count toward the daily fluid intake in the vast majority of persons (40). And, to a lesser extent, the same may be true for mild alcoholic beverages (79a, 84), such as beer consumed in moderation. Yet, the interdiction of these two types of beverages continues to be emphasized by proponents of 8×8 (3, 10, 17, 26, 42, 43, 59). Since for many adults caffeinated and alcoholic beverages constitute nearly one-half (Table 2) or slightly more (38) of the daily fluid intake, lifting these two restrictions raises the "effective" mean daily drinking fluid intake of adult Americans from the seemingly paltry amount of ~900 ml to the respectable one of 1,700 ml. And the last figure, of course, does not include the water we derive from solid foods and metabolism (Table 3; Refs. 29, 46). Some think that even 1,700 ml may be as much as 1 liter in excess of what sedentary American adults need to drink to maintain physiological homeostasis (38).

Thus I have found no scientific proof that we must "drink at least eight glasses of water a day," nor proof, it must be admitted, that drinking less does absolutely no harm. However, the published data available to date strongly suggest that, *with the exception of some diseases and special circumstances, such as strenuous physical activity, long airplane flights, and climate*, we probably are currently drinking enough and possibly even more than enough.

AN INVITATION FOR DIALOGUE

Having found no evidence in support of 8×8 has placed me in the awkward position of having to prove a negative. It is conceivable that a further search will unearth work that disproves my conclusion, in support of which I have cited peer-reviewed publications. I hope, therefore, that anyone who knows of contrary scientific evidence will bring it to my attention.

NOTE ADDED IN PROOF

The article cited in Ref. 10 can no longer be found on the website of the Tea Council. The Council now posts another article on hydration, which presents a more moderate view and cites scientific references (http://www.teahealth.co.uk/th/facts/6.htm).

S. A. Gorman, Information and Education Services Librarian at the Dana Biomedical Library of Dartmouth Medical School, spent innumerable hours conducting the literature searches and expediting the loan of many books and articles. The appearance of her name on the title page of this article reflects her essential role in the project.

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SEARCH STRATEGY

Because our search for scientific evidence in support of the dictum that we ". . .drink at least eight glasses of water a day" came up empty, it seems important to list here the various approaches we used in our efforts to find pertinent articles.

Electronic Searches

Many electronic databases were explored, including MEDLINE, BIOSIS Previews, CAB Abstracts, Science Citation Index, ABI/INFORM Global through ProQuest Direct, the World Wide Web, the OCLC Union Catalog through WorldCat, and the Research Libraries Group Union Catalog. "Drinking," "water—administration and dosage," and "optimal fluid intake" are examples of terms and phrases searched. The last led us to the article by Dr. A. Grandjean (40) and got us started on the pertinent scientific literature.

Nutritionists

In the absence of scientific articles, personal contacts with nutritionists turned out to be the best resource. Having conducted similar searches in vain, these nutritionists were frustrated by the perpetuation of 8 × 8 and offered tremendous help freely. They were Dr. Abby G. Ershow (Nutrition Program Officer, National Heart Lung Blood Institute, NIH), Dr. Ann C. Grandjean (Executive Director, Center for Human Nutrition, University of Nebraska Medical Center), Dr. Barbara J. Rolls (Guthrie Chair, Department of Nutrition, Pennsylvania State University), Dr. Elizabeth M. Whelan (President, American Council on Science and Health), Dr. Allison A. Yates (Director, Food and Nutrition Board, National Academy of Sciences), and Dr. Paula R. Trumbo (Senior Program Officer, Food and Nutrition Board, National Academy of Sciences).

Colleagues

Personal inquiries with ~15 colleagues who specialize in the area of water balance resulted in prompt responses. None of them knew the origin of 8 × 8 nor (with one possible exception) of published articles that support the claim. The possible exception was Dr. Lise Bankir, whose views have been described under POSSIBLE BENEFITS OF A HIGH WATER INTAKE: *Speculative Advantages*. Because naming these colleagues might draw them into the controversy over 8 × 8 without their permission, I will not list them here; however, they know who they are and I thank them for their efforts.

Authors of Lay Articles

I received no replies from three authors of lay articles whom I had asked for the sources and scientific evidence for their assertions and recommendations.