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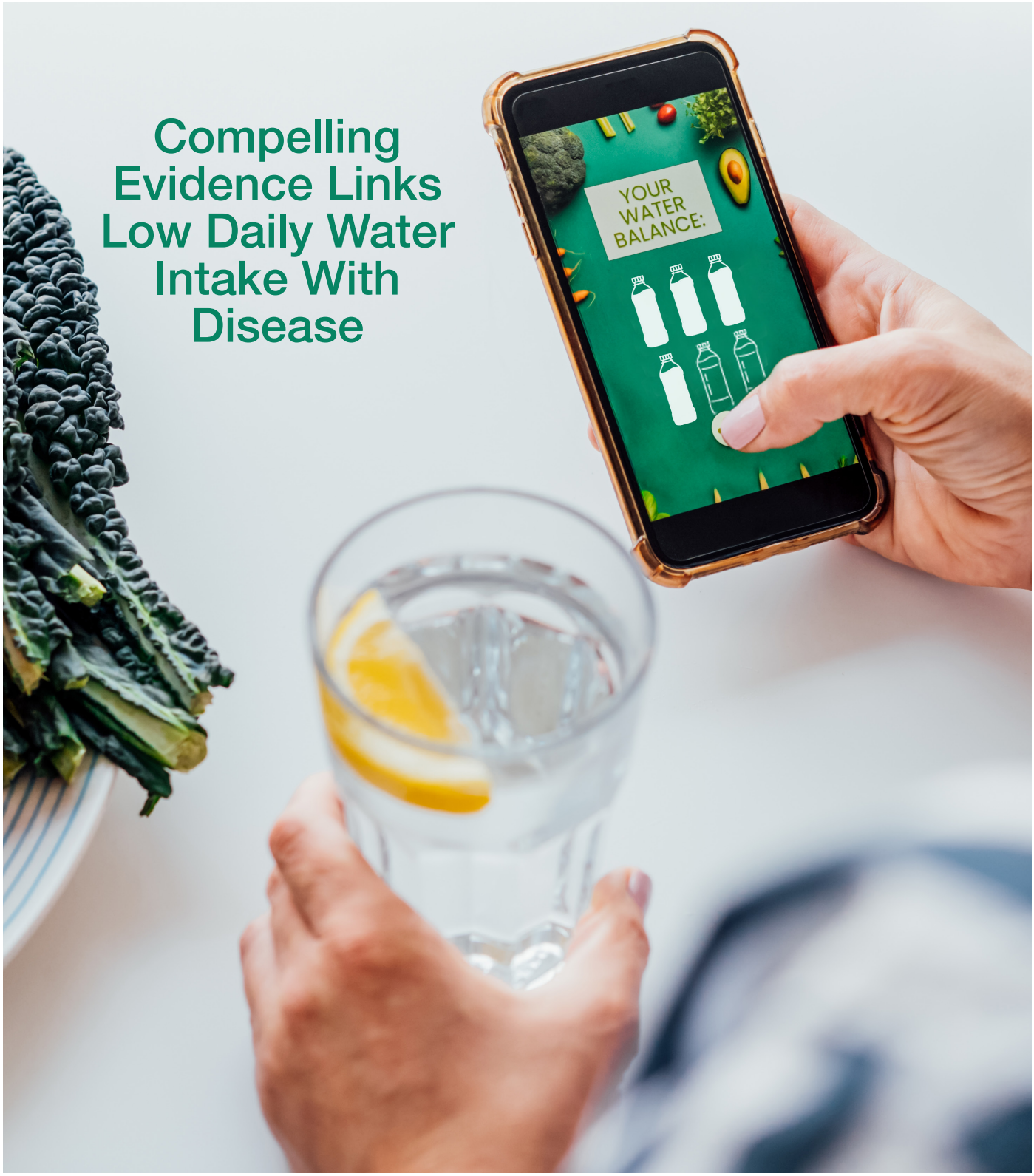
Compelling Evidence Links Low Daily Water Intake With Disease



By Lawrence E. Armstrong, PhD, FACSM

That water is essential to life and optimal health is widely recognized. Water supports many bodily functions (e.g., digestion, metabolism, blood circulation, regulation of body temperature, and excretion of waste products) and generally accounts for more than 55% of one's body weight. However, for reasons that have yet to be unraveled, some individuals consume too little water each day. That daily pattern of low water intake (LWI) may be due to established drinking patterns learned during childhood, cultural customs, or a weak thirst sensation.

The adults in this LWI group have been identified in several research studies reporting that 25–35% of adults in the United States and Europe habitually consume less than 1.5 liters of water per day (Armstrong et al., 2020). A 1.5-liter daily consumption rate is considerably below the daily Adequate Intakes recommended by the European Food Safety Authority and the U.S. National Academy of Medicine: 2.0 and 2.7 liters per day for women and 2.5 and 3.7 liters each day for for men, respectively (EFSA Panel, 2010; Institute of Medicine USA, 2004). [The volume of 1 liter is 6% larger than 1 liquid quart.] Two assumptions were fundamental to the development of these Adequate Intake volumes. First, water and adequate hydration are essential for health. Second, insufficient daily water intake may lead to medical disorders or diseases.

Although a number of publications have suggested that routine LWI is unhealthy, few previous research studies have evaluated the relationship between LWI and multiple chronic diseases or a shortened lifespan. Consequently, an important question remains unresolved: "Does chronic inadequate daily water intake lead to disease and/or does it reduce life span?" This question stimulated a research review article that I and three colleagues—Colleen X. Muñoz, PhD, and Michael F. Bergeron, PhD, University of Hartford, Hydration Health Center, and Stavros A. Kavouras, PhD, Arizona State University, Hydration Science Lab—published recently in the journal *Nutrition and Health* (Armstrong et al., 2024).

Between 25–35% of adults in the United States and Europe habitually consume less than 1.5 liters of water per day.

To prepare for this publication, we conducted manual online searches of the PubMed, Embase, and Google Scholar research databases, using 47 keywords and predefined search criteria. The targeted searches focused on the relationships between low daily water/fluid intake (LWI) or two urine biomarkers of dehydration (UBD) (i.e., low urine volume or high urine concentration) with a greater disease risk, higher incidence of medical disorder, or premature mortality. Initially, 3,903 articles were identified based on their titles and abstracts. Subsequent evaluations of full length PDF versions identified the 96 studies that were acceptable for inclusion.

Table 1 (see p.3) summarizes our findings regarding the associations of LWI or UBD with 10 medical conditions (column 1). To be included in Table 1, each disease had to appear in at least three relevant research articles meeting the screening requirements (discussed below). Column 2 describes the strength of evidence, as determined by the unanimous consensus of the authors. The strength of evidence was based

TABLE 1. RESEARCH STUDIES THAT EVALUATED ASSOCIATIONS OF LWI AND/OR UBD WITH A HUMAN DISEASE RISK, INCIDENCE, RECURRENCE, OR MORTALITY.

MEDICAL CONDITION, DISEASE, OR MORTALITY	STRENGTH OF EVIDENCE (RATIO OF STUDIES SHOWING AN ASSOCIATION TO THOSE SHOWING NO ASSOCIATION)	STUDIES REPORTING DIFFERENT ASSOCIATIONS FOR MEN AND WOMEN
Kidney stones	Strong evidence for an association (25:2)	1
Type 2 diabetes / hyperglycemia	Strong evidence for an association (8:3)	1
Bladder/urinary tract cancer	Conflicting evidence (12:16)	5
Chronic kidney disease	Conflicting evidence (11:4)	
Colorectal cancer	Conflicting evidence (7:3)	1
Urinary tract infection	Insufficient evidence to determine an association (3:3)	
Autosomal dominant polycystic kidney disease	Insufficient evidence to determine an association (2:2)	
Stroke mortality	Insufficient evidence to determine an association (1:2)	
Fatal coronary heart disease	Insufficient evidence to determine an association (3:4)	1
All-cause mortality (death due to all causes)	Evidence suggests lack of an association (1:4)	

Notes: LWI was reported in these studies as low plain water intake or low total fluid intake (water + beverages + food moisture). The two UBD were low urine volume and/or high urine concentration (signifying dehydration). Of the 96 separate studies in column 2, 11% reported data for multiple diseases. Determination of the strength of evidence considered both the ratio of studies (column 2) and their research designs; randomized clinical trials, systematic reviews, and meta-analyses provided the strongest evidence. This table has been modified from (Armstrong et al., 2024) under the terms of the Creative Commons Attribution-NonCommercial 4.0 International License (*https://creativecommons.org/licenses/by-nc/4.0/*).

on the total number and ratio of studies in column 2 of Table 1, as well as the strength of research design; randomized clinical trials, systematic reviews, and meta-analyses (i.e., analyzing data from different studies conducted on the same subject) provided the strongest evidence. The authors concurred that the evidence was strong for two diseases: kidney stones and type 2 diabetes (discussed below). Evidence was insufficient or conflicting for the other seven disorders/diseases in Table 1.

Column 3 in Table 1 shows that different associations were reported for five diseases. This important finding suggests that LWI may affect women and men differently. Considering the complexity of disease development, unraveling the underlying causes of sex differences will require a considerable number of new investigations across multiple populations that are specific to each medical condition. Female-male hormone differences provide a logical starting point for those investigations.

All-cause mortality

In the final row of Table 1, the evidence suggests that neither LWI nor UBD were associated with all causes of mortality. This does not apply to any single cause of death. However, one research investigation provides several interesting insights. Allen et al. (2019) analyzed the data of 15,792 adults aged 45 to 64 years, from four USA communities (ARIC investigators, 1989) and determined that human hydration status predicted

Insufficient daily water intake may lead to medical disorders or diseases.

the development of multiple age-related degenerative diseases and that even subclinical mild hypohydration affected long-term health outcomes. In that same publication (Allen et al., 2019), animal experiments evaluated the long-term disease-related effects of LWI and UBD across the lifespan. Mice were water restricted starting at the age of 1 month, and consumed only gelled food containing 30% water and 70% dry food. During the first 12–14 months of life, the water-restricted mice were in a state of low-grade inflammation; also, their entire lifespan was shortened by about 6 months (18%), when compared to a control group of mice that had free access to water and consumed the same diet. In those experiments, animal research allowed clarification of cellular processes that would be difficult or unethical to explore in human subjects.

Kidney stones

Assessment of the existing literature demonstrated that strong evidence supports an association of kidney stones with LWI and/or UBD (Table 1). When kidney stones develop, urine supersaturation and crystal formation are the indispensable first steps. Thus, the primary goal of preventing kidney stones from recurring is consistently producing a dilute urine. To accomplish that goal, experts (Pak et al., 1980; Daudon et al., 2005) and professional medical organizations (Qaseem et al., 2014; Skolarikos et al., 2015) recommend consuming enough water to produce 2.0 – 2.5 liters of urine per day (Armstrong et al., 2024).

Type 2 diabetes with hyperglycemia

Type 2 diabetes (T2D) involves cellular resistance to insulin that is produced normally by the pancreas; consequently, the body is unable transport glucose into cells for fuel. Most T2D patients do not require insulin injections but typically are obese, and obesity itself causes some degree of insulin resistance. Primarily due to a rise in obesity, the prevalence of T2D is increasing and now exceeds 500 million patients worldwide. T2D is largely preventable and, in some cases, potentially reversible if identified and managed early in the disease course (GBD 2021 Diabetes Collaborators, 2023). The chronic elevated blood glucose levels (i.e., hyperglycemia) in T2D may result in long-term damage, dysfunction, and failure of different organs including the eyes, kidneys, nerves, heart, and blood vessels (American Diabetes Association, 2013).

Extensive manual searches of scientific databases identified strong evidence for an association of T2D with LWI and/or UBD (Table 1). Although the exact mechanism by which LWI may affect glucose metabolism is not known (Johnson et al., 2017), several theoretical mechanisms have been reviewed elsewhere (Armstrong et al., 2024).

Opportunities to reveal more links between hydration and health

The existing research evidence is insufficient or conflicting for seven of the medical conditions in Table 1. An additional 11 disorders/diseases are presently understudied and did not meet the criterion (i.e., three publications minimum) for inclusion in Table 1: type 1 diabetes (0), breast cancer (0), metabolic syndrome (0), dementia (1), Alzheimer's disease (0), depression (0), chronic lung disease (0),

Research evidence strongly suggests that low water intake is associated with two diseases—kidney stones and type 2 diabetes—and may influence the development of multiple age-related degenerative diseases.

coronary artery disease (1), heart failure (0), mitral valve prolapse (0), and hypertension (0). The numbers in parentheses denote the number of publications that were discovered during literature searches. Clearly, those 11 disorders/diseases have not been studied adequately.

Clarifying these associations (e.g., by conducting controlled, randomized, long-term clinical studies to reach more definitive conclusions) will support the development of updated water consumption guidelines that will reduce the risk, incidence, and severity of specific diseases.

Nonetheless, strong evidence exists for associations between LWI or UBD and both kidney stones and T2D. This suggests that great public health value (i.e., for millions of kidney stone and T2D patients) may result from increased daily water intake—a simple and cost-effective dietary modification. **BWR**

Lawrence E. Armstrong, PhD, *Professor Emeritus, University of Connecticut is a Trustee of the Drinking Water Research Foundation. He was recognized recently as a member of the "Stanford University 2023 Top 2% of Scientists."*

ADDITIONAL INFORMATION

The entire open access review article and a complete version of Table 1 can be downloaded at *https://pubmed.ncbi.nlm.nih.gov/38515347/*. Simply click on "full text links."

For further details about the health benefits of adequate daily water intake, you can consult the following articles from past issues of *Bottled Water Reporter.*

- Roselyne Wagner and Isabelle Guelinckx. How much water should you drink each day? Jan/Feb 2017, pg. 14-19.
- Lawrence Armstrong. Drink more water each day to optimize mood and mental tasks. Jan/Feb 2017, pg. 20-23.
- Christine Umbrell. Revolutionary hydration health center. Revealing the hydration-health connection. Winter 2023-2024, pg. 11-15.

References

Allen MD, Springer DA, Burg MB, Boehm M, Dmitrieva NI. 2019. Suboptimal hydration remodels metabolism, promotes degenerative diseases, and shortens life. *JCI Insight* 4(17): 1–17.

ARIC investigators. 1989. The Atherosclerosis Risk in Communities (ARIC) Study: design and objectives. *American Journal of Epidemiology* 129(4): 687–702.

American Diabetes Association. 2023. Diagnosis and classification of diabetes mellitus. *Diabetes Care 36* (Supplement 1): S67-S74.

Armstrong LE, Bergeron MF, Muñoz CX, Kavouras SA. 2024. Low daily water intake profile—is it a contributor to disease?. *Nutrition and Health* e-pub ahead of print. *https://pubmed.ncbi.nlm.nih.gov/38515347/*

Armstrong LE, Muñoz CX, Armstrong EM. 2020. Distinguishing low and high water consumers—a paradigm of disease risk. *Nutrients* 12(3): article 858, 27 pg.

Daudon M, Hennequin C, Boujelben G, Lacour B, Jungers P. 2005. Serial crystalluria determination and the risk of recurrence in calcium stone formers. *Kidney International* 67(5): 1934-43.

EFSA Panel on Dietetic Products, Nutrition, and Allergies. 2010. Scientific Opinion on Dietary reference values for water. *EFSA Journal* 8(3): article 1459, 48 pg.

GBD 2021 Diabetes Collaborators. 2023. Global, regional, and national burden of diabetes from 1990 to 2021, with projections of prevalence to 2050: a systematic analysis for the Global Burden of Disease Study 2021. *The Lancet* 402(10397): 203-234.

Institute of Medicine USA. 2004. Dietary Reference Intakes for Water, Potassium, Sodium, Chloride, and Sulfate. Washington, D.C.: National Academy Press, 1–640.

Johnson EC, Bardis CN, Jansen LT, Adams JD, Kirkland TW, Kavouras SA. 2017. Reduced water intake deteriorates glucose regulation in patients with type 2 diabetes. *Nutrition Research* 43: 25-32.

Pak CY, Sakhaee K, Crowther C, Brinkley L. 1980. Evidence justifying a high fluid intake in treatment of nephrolithiasis. *Annals of Internal Medicine* 93(1): 36–39.

Qaseem A, Dallas P, Forciea MA, Starkey M, Denberg TD. 2014. Dietary and pharmacologic management to prevent recurrent nephrolithiasis in adults: a clinical practice guideline from the American College of Physicians. *Annals of Internal Medicine* 161(9): 659–667.

Skolarikos A, Straub M, Knoll T, Sarica K, Seitz C, Petrík A, Türk C. 2015. Metabolic evaluation and recurrence prevention for urinary stone patients: EAU guidelines. European Urology 67(4): 750-763.