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Human Water Needs

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Healthy humans regulate daily water balance remarkably well across their lifespan despite changes in biological development and exposure to stressors on hydration status. Acute or chronic body water deficits result when intakes are reduced or losses increase, but day-to-day hydration is generally well maintained so long as food and fluid are readily available. Total water intake includes drinking water, water in beverages, and water in food. Daily water needs determined from fluid balance, water turnover, or consumption studies provide similar values for a given set of conditions. A daily water intake of 3.7 L for adult men and 2.7 L for adult women meets the needs of the vast majority of persons. However, strenuous physical exercise and heat stress can greatly increase daily water needs, and the individual variability between athletes can be substantial.

Key words: body water needs, fluid balance, fluid homeostasis, hydration

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INTRODUCTION

Water is the quintessential nutrient of life. Despite its well-established importance, however, it is ironically often ignored as a dietary constituent. During the past decade, considerable public attention has focused on the importance of adequate hydration, but the scientific basis for the often-recommended daily water consumption rates is unclear.[1] The National Research Council (NRC) had recommended a daily water intake of approximately 1 mL/kcal of energy expended,[2] but data supporting that value are sparse.[3] The Food and Nutrition Board of the Institute of Medicine (IOM) recently convened a panel of experts to set new Dietary Reference Intakes (DRIs) for water and electrolytes to expand and replace the Recommended Dietary Allowances (RDAs). The results of this extensive effort were published in 2004.[4] The purpose of this review is to briefly summarize the results of that effort, with a narrow emphasis on reviewing water needs for healthy people across their lifespan. In addition, this paper will give additional attention to the effects of physical exercise and heat exposure on daily water needs.

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REGULATION OF WATER BALANCE

Water (total body water) is the principal chemical constituent of the human body. For an average young adult male, total body water represents 50% to 70% of body weight.[5] Variability in total body water is primarily due to differences in body composition. Lean body mass is about 73% water and fat body mass is 10% water.[6] Differences in total body water often attributed to age, gender, and aerobic fitness are mostly accounted for by body composition.

Total body water is distributed into intracellular fluid and extracellular fluid compartments, which contain about 65% and 35% of total body water, respectively. The extracellular fluid compartment is further divided into the interstitial and plasma spaces. An average 70-kg male has about 42 L of total body water, so the intracellular fluid compartment contains about 28 L of water and the extracellular compartment about 14 L of water, with about 3.2 L in plasma and 10.8 L in the interstitium. These are not static volumes, but represent the net effects of dynamic exchange.[7]

Approximately 5% to 10% of total body water is turned over daily,[8] being distributed via obligatory (non-exercise) fluid loss avenues (Table 1). Respiratory water loss is influenced by the inspired air (temperature and humidity) and the pulmonary ventilation. Metabolic water is formed by oxidation of substrates and is roughly offset by respiratory water losses. Urine output generally approximates 1 to 2 L per day, but can be increased by an order of magnitude when consuming large volumes of fluid. This large capacity to vary urine output represents

Table 1. Daily Water Losses and Production

Reference	Source	Loss (mL/d)	Production (mL/d)
Hoyt and Honig, 1996[60]	Respiratory loss	−250 to −350	
Adolph, 1947[61]	Urinary loss	−500 to −1000	
Newburgh et al., 1930[24]	Fecal loss	−100 to −200	
Kuno, 1956[62]	Insensible loss	−450 to −1900	
Hoyt and Honig, 1996[60]	Metabolic production		+250 to +350*
	Total	**−1300 to −3450**	**+250 to +350**
	Net loss (sedentary)	**−1050 to −3100**	
Burke, 1997[40]	Sweat losses in various sports	−455 to −3630	
	Net loss (athlete)	**−1550 to −6730**	

Table modified from IOM.[4] Used with permission.
*Metabolic water production based on 2500–3000 kcal daily energy expenditure. Additional water production with exercise is assumed offset by parallel respiratory losses (as illustrated above with rest).

the primary avenue to regulate net body water balance across a broad range of fluid intake volumes and losses from other avenues.[4] Sweat losses vary widely and depend upon the physical activity level and environmental conditions.[9]

Net body water balance (loss = gain) is regulated remarkably well day-to-day as a result of thirst and hunger drives, coupled with ad libitum access to food and fluids to offset water losses.[4] This is accomplished by an intricate interplay between neuroendocrine and renal responses to body water volume and tonicity changes,[10] as well as non-regulatory, socio-behavioral factors.[11] These homeostatic responses collectively ensure that small degrees of over- and under-hydration are readily compensated for in the short term.

Using water balance studies, Adolph[12,13] concluded that daily body water varied narrowly between 0.22% and 0.48% in temperate and warm environments, respectively. Although acute mismatches may occur due to illness, exposure, or exercise, the fact that intakes are generally adequate to offset avenues of net loss from day to day is a reproducible phenomenon[14] and a cornerstone basis for establishing water intake requirements from large population surveys.[4] It is recognized, however, that after significant body water losses such as those associated with exercise-heat stress, many hours of rehydration and solute consumption may be needed to reestablish body water losses.[15] Specific concepts associated with exercise-heat stress and fluid replacement are elaborated upon later in this review.

More recently, isotope-labeled water has been used to measure body water turnover and water needs. Rates of body water turnover assume a balance between influx and efflux, and are determined by following the decline in hydrogen isotope over time. These values are generally higher than in water balance studies, because subjects are often more active or are exposed to outdoor environments, but high correlations have been reported between both direct and water turnover methodologies in infants.[16,17] Studies in adults also support close agreement between the two methods when similar but independent investigations of sedentary and active people are compared[18-20] (Figure 1).

HUMAN WATER NEEDS

Normal water needs range widely due to numerous factors (e.g., metabolism, diet, climate, clothing)[4]; thus, normal hydration is compatible with a wide range of fluid intakes. Human water requirements should not be based on a "minimal" intake, as this might eventually lead to a deficit and possible adverse performance and health consequences.[4] Instead, the Food and Nutrition Board of the IOM bases water needs on adequate intake (AI). The AI is based on experimentally derived intake levels that are expected to meet nutritional adequacy for essentially all members of a healthy population. Data

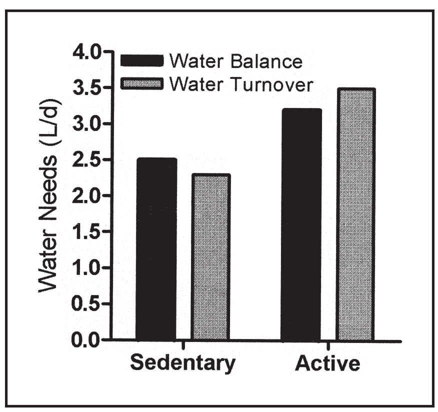

Figure 1. Comparison of water needs estimated using water balance or water turnover methodologies for sedentary and active people. Data are from Consolozio et al., 1968[20] Greenleaf et al., 1977,[19] and Leiper et al., 2001.[18]

from water balance, water turnover, and total water intake surveys were considered.

For infants, water needs are met primarily by the consumption of human milk or formula.[4] Throughout development, more and more water is acquired by a variety of beverages and food. Developmentally, total body water per kilogram of body mass is highest in infancy and gradually declines[6] as fluid regulatory mechanisms mature. Although it is not until mid- to late puberty that responses such as sweating become similar to adults,[21] thirst and hunger are primitive biological drives that compensate well for obligatory water losses.

Fluid balance studies show that daily water needs increase with age from early infancy (~0.6 L) through childhood (~1.7 L).[22,23] For adults, the daily water needs of men approach 2.5 L if sedentary,[3,24] and increase to about 3.2 L if performing modest physical activity,[19,25] while more active adults living in a warm environment have daily water needs of about 6 L.[26]

Examination of water turnover studies indicates that daily water turnover is 3.3 L and 4.5 L for sedentary and active men, respectively.[8,18,27-33] For more active populations, even higher values (>6 L) have been reported.[33] Sparse data are available on women, but they generally exhibit lower daily water turnover rates (~0.5—1.0 L less) than their male counterparts. Limited data are available regarding the influence of advancing age on body water turnover, but reported values are not dissimilar from younger adults. As age progresses for both genders, physical activity might decrease and the fluid regulatory capacity can decline due to reduced renal concentrating and diluting capacity[34-36] and to a diminished thirst drive.[37] Despite these facts, hydration status continues to be normal throughout life.[4]

Total daily water intakes from the Third National Health and Nutrition Examination Survey (NHANES III)[4] were obtained from a very large population. The results indicate that for children and adults, about 80% of total daily water intake is obtained from beverages and about 20% from food.[4] Both water sources are considered in the total, since bioavailability of water is similar for both beverage and food sources of water. Most importantly, the NHANES data indicate that at all age groups (12—71+ years) and at all levels of consumption, the participants were in water balance (i.e., they had normal plasma osmolality).

The NHANES results were consistent with data obtained from water balance and water turnover studies. For adult males, the total daily water intake was about 3.31 L for the fifth decile and increased to over 6 L for the tenth decile. Because of the close agreement among experimental methods (water balance, water turnover, and consumption) and the evidence for normal water balance, the population survey data (median total intake) were employed to set the AI levels for children and adults.

Figure 2 provides a summary of the median total water intake for each age group for men and women.[4] These data were used to set the AI. For adult men and women, the AI was 3.7 and 2.7 L per day, respectively, and required no adjustment for advancing age. For pregnant and lactating women, the AI was increased by 0.3 L and 1.1 L, respectively. Like other AIs for healthy people, water intakes below or above the AI may not impose any health risk (or adverse performance consequences) because of the extreme variability in human water needs. Likewise, the AI should not be interpreted as a minimal water intake. Approximately 1 to 2 L/d are required to replace obligatory losses for sedentary adults residing in temperate climates (Table 1). The IOM clearly documented that maintaining euhydration is important, as acute and chronic body water deficits can adversely impact human health and performance. The AIs were not intended for use by competitive athletes or workers performing strenuous activity for extended durations in hot weather. Thus, higher water needs may be required for those who are more physically active, especially in hot environments.

WATER NEEDS AND PHYSICAL ACTIVITY

Physical activity results in increased water requirements that parallel sweat losses for evaporative heat exchange.[38] Survey data of individuals reporting five or more days of leisure time activity per week show higher median water intakes on the order of 0.5 L/d compared with their less-active counterparts.[4] Water turnover studies demonstrate that higher volumes of daily (50 km of cycling) or weekly (100 km of running) activity in a

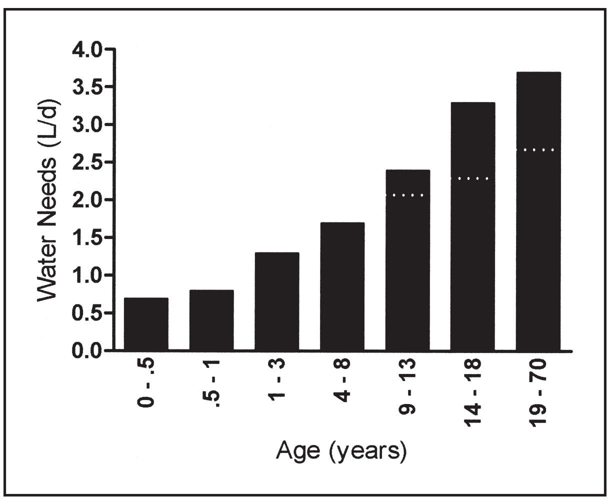

Figure 2. Water needs across the lifespan. Columns with dashed horizontal lines represent requirements for girls or women in that age category. Data are from the IOM.[4]

temperate environment increases water flux by 1.2 to 1.4 L/d, owing primarily to sweat volume loss and replacement.[18,29] The same activities in warmer environments would exacerbate the outcome.

Figure 3 depicts generalized modeling approximations for daily sweating rates as a function of daily metabolic rate (activity level) and air temperature. Applying this prediction model (the details of which are elaborated upon elsewhere[4]), it is clear that water requirements can increase 2- to 6-fold from baseline by simple manipulation of either variable. For example, daily water requirements for any given energy expenditure in temperate climates (20°C) can triple in very hot weather (40°C) (Figure 3). In addition to air temperature, other environmental factors also modify sweat losses; these include relative humidity, air motion, solar load, and choice of clothing for protection against environmental elements. Therefore, it is expected that water losses, and therefore water needs, will vary considerably among moderately active people based on changing extraneous influences.

The magnitude of sweat losses incurred during exercise in a warm environment is dependent primarily on exercise intensity and duration.[38] Heat gain from metabolism is balanced by both dry and evaporative (sweating) heat loss, but very high metabolic rates coupled with warm weather demand a larger biophysical requirement for evaporative cooling,[39] leading to greater sweat losses and, subsequently, larger water requirements. It is therefore expected that athletes will require relatively more fluid to match their greater sweat losses and maintain water balance. But, again, sweating rates range widely between (sports) and within (position) different athletic arenas.[40] Even under standardized conditions in fairly homogeneous athlete populations, inter-subject sweating variability is significant.[41]

Acute exercise sweat losses commonly fall within a range of 1 to 2 L/h for team[40] and individual[42] endurance sports. Table 2 provides sweating rates reported for athletes participating in a variety of sports.[42] Although rarely sustainable for more than a few hours due to the level of exertion required, such losses can markedly affect water requirements (Table 1). Maximal human gastric emptying rates are also variable and influenced by numerous factors, but approximate typical sweat losses (1–1.5 L/h).[43,44] Despite this fact, only about half of sweat losses are voluntarily replaced during exercise,[40,45,46] which generally results in moderate acute water deficits in team (1%–2%)[40] and competitive endurance sports (1%–4%),[46] although individual losses in excess of 5% have been reported many times for prolonged, continuous exercise.[47-51]

A modest daily exercise sweat loss of 1.4 L will increase obligatory daily water requirements by about 45%, all other factors remaining constant (Table 1). Although this is a relatively small volume, larger losses do occur (Table 1) and can be difficult to replace and retain in the short term.[15] Longer recovery periods (~24 h) of ad libitum drinking, especially when combined with food intake and ample electrolyte replacement,[52,53] al-

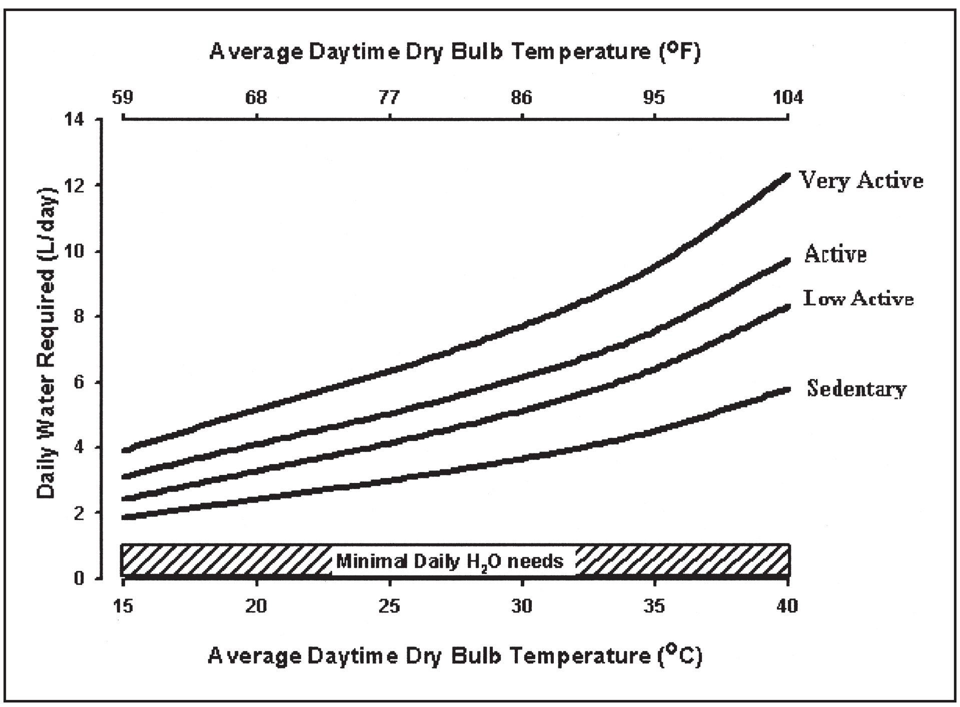

Figure 3. Water needs estimated from sweat loss predictions due to changes in physical activity and air temperature. Figure is from the IOM[4] (used with permission).

Table 2. Sweating Rates for a Variety of Sports

Sport	Mean	Range
	L/h	
Water polo	0.55	0.30 to 0.80
Cycling	0.80	0.29 to 1.25
Cricket	0.87	0.50 to 1.40
Running	1.10	0.54 to 1.83
Basketball	1.11	0.70 to 1.60
Soccer	1.17	0.70 to 2.10
Rugby	2.06	1.60 to 2.60

Data are from Rehrer and Burke, 1996.[42]

lows a return to normalcy. This is true even when daily water losses are significant (4% body mass)[54] and daily water turnover is approximately 40% to 50% above baseline.[18,29] Although daily strenuous activity in a hot environment can result in mild water balance deficits, even with unlimited access to food and fluids,[15,55,56] adherence to recognized water intake guidance[57,58] under similar conditions prevents accumulating water deficits, as determined by daily body mass stability.[59]

CONCLUSIONS

Healthy humans regulate daily body water balance with precision despite highly variable water needs and intakes and exposure to variable stressors on hydration status. So long as food and fluid are readily available, this is accomplished by eloquent physiological and behavioral adaptations. Among the greatest challenges to body water homeostasis is exercise and exercise-heat stress. However, normal hydration can be achieved with a wide range of water intakes by sedentary and active people across the lifespan.

PANEL DISCUSSION

Eric Jéquier: I have a question about adaptation to the heat environment. There have been several studies on this phenomenon. Do you think that adaptation may have an effect and may decrease this water requirement that you have mentioned?

Michael Sawka: No. There have been studies by Adolph and in our laboratory, and essentially all of these studies pretty well show the same thing, at least for what they were studying in terms of the ability to thermoregulate and tolerance to exercise and heat stress. There is no real adaptation in terms of tolerance. There are some physiological adaptations, though, that occur with heat acclimatization that influence fluid balance. Now, if you look at requirements, the first is that as you acclimatize you increase your ability to produce sweat, so your water losses are going to be greater. Total body water will also go up a little bit. How much is controversial, but probably about 1 to 3 L at the most. For a given decrease in total body water, what you see is that you have that same increase in core temperature or the same decrement in the thermoregulatory system. Now, there are also some other changes. For example, when you start using parameters like plasma markers as measures of hydration, one of the things that you see is that for a given level of dehydration, an unacclimatized person is going to have a much larger reduction of plasma volume. And as the person acclimatizes, in addition to increasing sweat, the sweat becomes more dilute so they retain sodium. This sets up an osmotic gradient to pull fluids from the intracellular spaces, so the plasma volume reduction is about one-half in heat-acclimatized compared with unacclimatized persons. So you see subtle changes when you are acclimatized; a decrease in plasma volume in proportion to about the level of dehydration, but none of them really correlate into any abatement of performance reduction, at least for the ways we've studied it.

Friedrich Manz: In the DRIs for water, serum osmolality was the primary indicator of hydration status. As serum osmolality concentrations were essentially identical for the first (lowest), fifth, and tenth deciles of daily total water intake within each age group, euhydration was assumed even in the decile with the lowest total water intake. The renal concentrating mechanism is stimulated by vasopressin. Low serum vasopressin levels result in a high diuresis and high levels in a low diuresis. Serum osmolality is the most important factor for vasopressin secretion. However, there are a lot of confounding factors influencing the relation of the serum levels of osmolality and vasopressin (e.g., genetic factors, blood volume, blood pressure, age, phase of the menstrual cycle, and drugs). Could it be that confounding factors equilibrated the difference in serum osmolality between the subjects in the lowest and those in the highest decile of water intake? Furthermore, plasma osmolality is an acute parameter, going up and down with circadian rhythm, whereas water intake is a 24-hour measurement. At what time was plasma osmolality determined?

Michael Sawka: There are two sets of osmolality. You have the first set of osmolalities that were obtained from the NHANES samples, which were obtained from many thousands of individuals. Very few of them had indications that they were consuming large amounts of water beforehand, so you probably had adequate time to retain fluid balance. In the second, you do see that osmolality goes up with age, as you would expect, by several osmoles, and you see some fluctuation that reflects many of the things that you mention. Now, in terms of the relationship between dehydration and osmolality, that was taken from a number of studies, most of which were very careful fluid balance studies. For the majority of those studies, those individuals achieved a certain hydration level, or were monitored over many days and essentially were in actual fluid balance or dehydrated, and were held there for some time. So there was a period of compensation. Essentially, if you give someone water or you dehydrate him and you wait long enough, 6 or 8 hours, the osmolality will come back. Either they return to euhydration or to a certain level reflective of their level of dehydration. We use it in the lab all the time. It's a very nice, precise relationship.

Friedrich Manz: In Muslim countries, the whole population is dehydrated during Ramadan, at least in the afternoon. Is dehydration associated with an increased risk of accidents or emergency cases? There are very few data in the literature. In a retrospective study of all road traffic casualties observed in a local hospital in the United Arab Emirates, a greater number of injuries was found during Ramadan than in the rest of the year (Bener A, Absood GH, Achan NV, Sankaran-Kutty M. Road traffic injuries in Al-Ain City, United Arab Emirates. J R Soc Health. 1992;112:273–276).

Michael Sawka: I don't know the specific study you are addressing, but in many studies that are epidemiological in nature that look at individuals during pilgrimages, there is a variety of factors that are changing: heat stress, fitness level, nutrition, a whole host of things, so to be able to go retrospectively back and pull out the effects of hydration would probably be difficult. But I do think that, based upon our observations and many experiments over the years, and those of my colleagues, there are a variety of changes that occur that very much would logically result in an increased injury rate, and they may be independent or accentuated by heat. I think it's a very fertile area of research.

Antonio Dal Canton: I wonder whether a 12-hour privation of water can be considered a way to become dehydrated, referring to Ramadan, for example. I take food and water only once a day at dinnertime and I feel well and believe that my plasma osmolality remains within the limits of normal range. In general, I think that our body has developed a great ability to resist insults, in terms of having water or not having water available. We have bottles of water in the refrigerator and tap water easily available, but up to 10,000 years ago, it was normal for our ancestors to go 12 or 24 hours, perhaps, without drinking. This does not mean that they developed pathological dehydration. Once again, I would go back to the definition of normality as a different concept from being in the ideal condition.

Patrick Ritz: If we focus on elderly people, and if I understand correctly, you said that is above 50 years of age in the NHANES study, you measured water intake and then added a little bit.

Michael Sawka: Yes, from that age beyond, essentially, the water intakes were a little bit lower than for younger adults, and knowing that older individuals have a reduced drive for thirst, knowing that there are changes in renal function, and also having essentially a smaller population available to arrive at those numbers, we felt it advisable to add a couple of hundred milliliters, so we wouldn't give the impression that water requirements decreased with aging. So, yes, those numbers are slightly inflated.

Denis Barclay: Dr. Shirreffs was describing earlier the phenomenon of people who perspire a lot. Is this a well-described phenomenon? Is there any known physiological basis for this, and for a given activity, what sort of range would there be in terms of sweat loss per hour?

Michael Sawka: First of all, you do see variability but there are also certain populations, such as individuals who have certain mutations for cystic fibrosis, who also have very high losses of sweat and sodium. So there is variability in sweat loss, just as there is variability for acclimatization to heat.

Irwin Rosenberg: Perhaps you might want to elaborate on this issue of the AI. When dealing with other nutrient requirements in the whole DRI process, we use AI as a kind of a fallback position when there isn't enough information to derive an estimated average requirement from which you could then calculate an RDA. It seems to me that when you're dealing with something like hydration, which is so well-regulated in the healthy individual, that there is even more reason to use an AI, because it does then represent the way in which, in a well-regulated environment, an intake can be representative of the actual requirement. Was that part of the thinking of your committee?

Michael Sawka: Although as a physiologist I was peripheral to those discussions, it was a fallback position. Essentially what we are saying with this AI is basically that this is what the vast majority of people consume and remain well hydrated. We recognize that there is considerable variability between individuals, but from the best that we can determine, normal healthy individuals, given adequate time, will maintain hydration. But we don't say that you have to drink 3.7 L a day. Essentially, what we are saying is that you're probably doing OK, whatever you're doing. That for an average person they consume about this amount and are well hydrated. You can go back and look through the beautiful experiments done by Dr. Adolph and see that if given adequate time, people will maintain fluid balance. If water is made available they will rehydrate adequately, and that's what we seem to have reconfirmed.

Tyko Persson: This is based on a very large US data set. Do you think there is any reason that these values will not be valid for Europe?

Michael Sawka: I really don't know. I assume the physiology is similar between Americans and Europeans, but lifestyle is different. People may or may not have more air-conditioning. People in Europe certainly seem to be leaner and more active and have different diets. Certainly we recognize the dietary impact affecting renal water loss. There probably is some variability and it's probably due more to lifestyle and what you're exposed to, so it very well could be different. And I'm sure not all Europeans are the same. The people who live in Lausanne may be different than the people who live in Paris, but they're all probably well hydrated. That much I would say: they're healthy.

Friedrich Manz: In the DRI for water of 2004, urine solute excretion on a typical western diet was estimated to be 650 mOsm/d. In our studies in Germany, mean urine solute excretion was 942 mOsm/d in men and 752 mOsm/d in women. In the literature, urinary solute excretion ranged from about 400 mOsm/d*1.73m^2 in sweet potato eaters in Papua, New Guinea to 1365 mOsm/d in Australian miners working very hard. Considering the data on urine solute excretion from several small studies in the United States, and the comparable levels of protein and sodium intake in American and German adults, urine solute excretion may be not so different. The main difference in the hydration status between the US and German population refers to fluid intake. In the United States, about 19% of water intake is from food and fluids; in Germany it is 32% in men and 35% in women. From a nephrological point of view, what percentage of the US population would be in the range of risk of hyperhydration?

Michael Sawka: On the question of hyperhydration, we went very thoroughly through the hyponatremia data for normal persons eating a normal American diet, and we just couldn't find any evidence that these people suffered from hyponatremia or adverse consequences of that. We didn't go back and look at solute load and then try to calculate water requirements. Basically, we used three avenues. We looked at water balance studies, we looked at water turnover studies, and we looked at consumption, and in all three avenues we came up with similar numbers and saw that individuals seemed to be well hydrated. We just could not find any evidence of any systematic dehydration or hyponatremia from hyperhydration. So those are the numbers and those are the data we looked at, and that's all I can really comment on.

Irwin Rosenberg: Well then, what are we to make of the differences that we were presented with earlier from Dr. Manz and Dr. Ferry and now from NHANES? Is the message here that we need the equivalent of an AI for each country? Or is the message that we need to look at and compare these data and try to understand why they appear to be different, in spite of the fact that there may be much greater similarities between European and American populations and Australian populations and so forth? Can we find some way to harmonize these data and to understand whether there are in fact numbers that can be used across numerous populations? Or are these national phenomena that have to be looked at as individual research questions?

Susan Shirreffs: The data that were cited from some of the water balance and water turnover studies were European data. So those numbers come from a number of European studies in addition to the United States.

Patrick Ritz: There are also probably some other data available. I am thinking about French data from the SU.VI.MAX study, where there are probably some indicators of water consumption. So if we are to compare countries, it is probably safer to pool together more than two.

Irwin Rosenberg: Under average conditions, we have 2.2 L for female adults and 2.9 L for male adults, which are close to the fluid intake recommendations in the United States. If you add the water from food, you end up with pretty much the same numbers that Dr. Sawka has been talking about, so I am trying to understand where we have consensus and where we don't.

Michael Sawka: I don't think the DRI panel would argue; maybe it's not 3.7 but 3.2 L, and that at 3.2 L, the average person is well hydrated. All we're saying is that it seems to be what they consume, and to the best of our knowledge they are well hydrated. Whether they are drinking 3.7 L, 2.8 L, or 7.6 L, all of these people seem to be in fluid balance, as a group. And it could very well be that as you go down more towards that minimal requirement that we talked about, that that number could be lower. It all depends on the context of what you're using that value for.

Irwin Rosenberg: Did your committee consider suggesting a range?

Michael Sawka: Essentially, we did give a range. We said, this is the number and there is quite a bit of variability. But essentially the number 3.7 L doesn't mean that you need to drink 3.7 L. Dr. Armstrong may need 2.7 L, Dr. Shirreffs may need 4.6 L, but I am pretty certain that they are probably both in fluid balance.

Patrick Ritz: Along the same lines, are we about to get rid of the milliliter of water per kilocalorie? Should we?

Michael Sawka: Well, we had thought about that, but decided that it really didn't add any additional useful information. We just came up with a rough number because there are a whole variety of factors that confound it. We decided to get away from that. We did not feel that there was any value added.

Friedrich Manz: In the DRI of 2004 for water, AI for metabolic water and water in fluids and food is 1.31 mL/kcal in men and 1.22 mL/kcal in women.

Patrick Ritz: Yes, but I think the concept within that is that if you use a milliliter of water per kilocalorie spent, you introduce a body size variability component. If we get rid of that, and I don't know whether it's correct or not, and we just stick to one number for water intake independent of body size, this number is supposed to be valid for a 50-kg person and a 100-kg person as well.

Michael Sawka: Again, we are not saying that the 3.7 L is adequate for all individuals. That's not the message we are trying to transmit. We're trying to say that median intake is 3.7 L. We are saying that for each individual it could be 3.7, 4.7, or whatever, but what we are saying is that what they are taking in is adequate and that there is a lot of variability and the median for that group is 3.7 L. The message is not that it's 3.7 L for all.

Antonio Dal Canton: I am wondering what we are talking about and for what kind of people we are now defining the right amount of water to be consumed in a day. If you send soldiers to fight in the desert, you have to know how much water should be provided for them. And that's the reason for having a committee, to understand what is the average need for water and to provide water in very special conditions. But in day-to-day life, what is the real meaning of understanding what is the average amount of water that people drink? Because it may be normal that I drink 1 L and that he drinks 2 L, and both of us will be normal. We will not have any problem with hydration. I would rather address our attention to special categories: the elderly, or people who have recurrent urinary infections, and so on, because in those patients, maybe it is useful to force the uresis and to increase their water intake daily beyond their natural intake. But, frankly, this discussion about the normal water intake in normal people living in civilized countries, having all the amount of water available without any restriction, it seems philosophical to me.

Patrick Ritz: When we were with Dr. Rosenberg on the committee for energy requirements, it was about the same discussion. When we discussed energy requirements, we were very careful to define minimal energy requirements, and those minimal energy requirements have nothing to do with optimal requirements. They are made for politicians in a country to know how much food should be produced for the country, or in disaster relief, for example. This was minimal energy requirement. I agree that there are regulators for energy intake and expenditure in the body, but we have a very easy marker, which is body weight. But for water, so far we have no good indicator of body hydration. Secondly, what we have been talking about since the beginning of the symposium is functional status associated with optimal hydration, and we have to work along these lines. In terms of energy, there is no functional status. We know what is excess and what is a shortage, but we have no data on the relationship between optimal energy intake and optimal health. So I think it is not irrelevant to discuss what is the mean intake of water for a population and to compare it from one to the other.

Friedrich Manz: Before the 1990s, RDAs were defined as the levels of intake of essential nutrients that are judged to meet the known nutrient needs of practically all healthy persons. Prevention of nutritional deficiencies was the primary concern. DRIs represent a new paradigm. Reference values are defined by a specific indicator of nutrient adequacy, which may relate to the reduction of the risk of chronic disease or disorder. Which are the specific indicators to identify the level of water intake to prevent dehydration and certain diseases in practically all persons? Free water reserve may be a physiologically founded and empirically based indicator to establish guiding values to prevent dehydration in almost all persons of a specific population. Epidemiological studies are needed on health outcomes given different hydration status and water intakes. In the United States and Germany, there is a trend to increase water intake. Should the AI values of the United States be adapted in the next revision of the DRIs for water? Thirty years ago, as a young pediatric nephrologist, I regularly collected 24-hour urine samples in children with kidney stones. I wondered why it was so difficult for certain children to increase their water intake even in the presence of clinical symptoms. Today, we know that the recurrence rate of kidney stones can be substantially decreased by an increased water intake. If, as in Germany, more than 5% of the population will develop urolithiasis, why should we not promote an increased water intake not only on the individual level, but also on the population level? There are at least three arguments for different AI levels for water in different countries. Firstly, the climate may be different. You cannot have the same recommendations for Sicily and Finland. Secondly, nutrition depends on culture and climate. Water content of food, therefore, is different. Thirdly, the osmolar load of a diet is different. Energy and water metabolism are combined in many ways. If we compare small and big animals or toddlers and adults, both energy and water requirement are related to body surface area. Breast-fed infants are an exception. With a mean urine osmolality of 120 mOsm/kg, their hydration status is very close to hyperhydration. Three factors may be responsible: a high metabolic efficiency of breast milk, a low osmolar load, and a high evolutionary pressure to increase water intake to prevent death from dehydration during infant diarrhea. Glycogen is an interesting molecule that stores both energy and water. With a relationship of 1 g of glycogen to 3 mL of water, it is a very ineffective form of energy storage, with only 1 kcal/g body mass compared with fat, which has a storage of 9 kcal/g. However, at rest, the water losses from lung, skin, and kidney are balanced by the water liberated by the simultaneous glycogen consumption. Thus, during the night the water is liberated and excreted in the same amount, relieving the body from any need for additional regulation. Thus, there are several physiologic arguments to express water requirement in relation to energy requirement in milliliters per kilocalorie.

Irwin Rosenberg: I think it's very important that we continue to consider this question that we have heard now more than once from Dr. Manz. For the requirements that Dr. Sawka described here, none of the three factors that went into setting the numbers were based on an epidemiological relationship between water and specific health outcomes. I think we have to come to grips with that limitation. At some point, I would argue that we are going to have to find a way to address the question posed by Dr. Manz, which is, is there within this range (which is very nicely regulated because we have kidneys), perhaps in the 90th percentile versus the 10th percentile, will we find one day that those populations that are drinking higher amounts or drinking lower amounts are either more susceptible or less susceptible to a number of the kinds of conditions that Dr. Manz reviewed and perhaps others as well? Somehow, I think that lack is going to have to come into our discussions again.

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