Chapter 15

Meeting Requirements for Fluids

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Water is the most essential of all nutrients. Investigators conducting a controlled diet study are obligated to ensure that participants have an adequate intake of water just as for all other nutrients except those under investigation.

Thirst is one of the most powerful of all physical drives, even more so than hunger, and is subjectively unpleasant. Because any continued experience of thirst will quickly derail the participant's adherence to the protocol, provisions must always be made to avoid this sensation. It is crucial that the participant not feel that water or fluids are being restricted except under special conditions of the protocol. Participants who are likely to be thirsty for any period of time should be given advance notice and suggestions for coping with the discomfort (for example, dissolving hard candy in the mouth). Conversely, if required intake is too high, participants may feel that they are ''forcing fluids,'' with an accompanying sense of gastric fullness and the inconvenience of extra trips to the bathroom.

For many people, intake of beverages such as tea, coffee, soda, juice, or plain drinking water is a habitual behavior incorporated into the daily routine. This dietary pattern, which is distinct from thirst (1), has implications for well-controlled feeding studies, because participants may find it difficult to change this behavior to comply with the requirements of a feeding study. This can lead to problems with recruitment and adherence. It is preferable to allow the participants to control their own intake of beverages in general and water in particular.

Allowances and Sources

Water Allowances

Water is required in the amount individuals need to allow normal physiological function without dehydration or overheating. Recommendations for water intakes are, however, set not as requirements but as allowances, which include a generous safety margin. The Food and Nutrition Board, National Research Council (2), estimates the water requirement to be 1 mL (or gram) of water per kilocalorie of diet under ordinary circumstances, but recommends an allowance of 1.5 mL/kcal to cover most variations in need. Additional water beyond this level is needed when using certain types of medications or under conditions of heavy exercise, heavy sweating, hot weather, high protein intake, or high sodium intake. For example, a 200-mEq sodium diet (4,600 mg Na/day) might necessitate a water allowance of 40 mL/kg body weight.

Water requirements are also increased in illness associated with diarrhea, fever, vomiting, or polyuria. Lactation increases the need for water, as does pregnancy. Water intake must be carefully monitored for persons whose sensation of thirst may be blunted, such as elderly individuals or athletes exercising in hot weather (2). Some situations, such as use of antihistamine or decongestant medications, may lead to a sense of dryness in the mouth without much change in actual water requirements.

Typical Quantities and Sources of Water Intake

Intakes of total water from all dietary sources (solid foods and soups, plain drinking water, and other beverages) have been estimated for the US population using data from the 1977–1978 USDA Nationwide Food Consumption Survey (3, 4). Tables 15-1, 15-2, and 15-3 show these values expressed as total g/day, g/kg/day, and g/kcal/day (1 g water = 1 mL water). There is considerable variation among individuals, with a 3-fold to 4-fold range between the 5th and 95th percentiles of intake. Variations in intake partially re-

Source: "Well-Controlled Diet Studies in Humans, A Practical Guide to Design and Management", American Dietetic Association, © 1999.

TABLE 15-1

Total Water Intake (g/day) by Age and Sex[1–3]

Sex	Age (yr)	Mean	SD[4]	Percentile Distribution 5	25	50	75	95
Males	<1[5]	1,152	324	642	922	1,127	1,344	1,731
	1–10[5]	1,594	517	848	1,235	1,531	1,895	2,538
	11–19	2,210	769	1,170	1,673	2,095	2,626	3,634
	20–64	2,515	916	1,310	1,889	2,374	2,976	4,244
	65+	2,407	778	1,329	1,886	2,305	2,832	3,799
Females	<1[5]	1,144	341	631	918	1,118	1,319	1,704
	1–10[5]	1,523	493	827	1,176	1,462	1,800	2,437
	11–19[6]	1,773	594	947	1,367	1,696	2,104	2,812
	20–64[6]	2,045	716	1,068	1,547	1,952	2,421	3,338
	65+	2,055	653	1,122	1,597	1,985	2,425	3,257
Pregnant women		2,076	743	1,085	1,553	1,928	2,444	3,475
Lactating women		2,242	658	1,185	1,833	2,164	2,658	3,353

[1]Total water intake from all sources (drinking water, beverages, and foods).
[2]1 g = 1 mL water.
[3]Adapted from Ershow AG, Cantor KP analysis (3) based on data from 1977-1978 USDA Nationwide Food Consumption Survey.
[4]SD = Standard deviation.
[5]Does not include breast-fed children.
[6]Does not include pregnant or lactating women.

TABLE 15-2

Total Water Intake (g/kg/day) by Age and Sex[1–3]

Sex	Age (yr)	Mean	SD[4]	Percentile Distribution 5	25	50	75	95
Males	<1[5]	153.0	52.9	86.1	114.9	146.2	178.8	247.7
	1–10[5]	76.4	32.8	34.5	53.3	70.2	93.5	137.2
	11–19	39.6	14.8	19.5	29.1	37.5	47.9	67.8
	20–64	32.3	12.4	16.2	23.7	30.2	38.7	55.3
	65+	32.9	11.3	17.2	25.3	31.6	39.0	53.5
Females	<1[5]	172.9	70.7	87.2	124.2	160.4	207.6	305.7
	1–10[5]	74.2	31.6	34.1	51.1	67.9	90.7	134.5
	11–19[6]	35.5	13.9	16.5	25.8	33.6	43.0	61.4
	20–64[6]	32.9	12.6	16.0	24.1	31.0	39.4	56.5
	65+	32.8	11.6	16.8	24.4	31.2	39.7	54.9
Pregnant women		32.1	11.8	16.4	22.8	30.5	40.4	53.5
Lactating women		37.0	11.6	19.6	28.4	35.1	45.0	59.2

[1]Total water intake from all sources (drinking water, beverages, and foods).
[2]1 g = 1 mL water.
[3]Adapted from Ershow AG, Cantor KP analysis (3) based on data from 1977-1978 USDA Nationwide Food Consumption Survey.
[4]SD = Standard deviation.
[5]Does not include breast-fed children.
[6]Does not include pregnant or lactating women.

flect physiological and environmental factors such as age, sex, season, region, body size, and pregnancy or lactation, but these account for only a relatively small fraction of the variance in water intake; other personal factors clearly play a large role as well. Day-to-day intakes of total water tend to be relatively constant for individuals (4).

In free-living US adults, the average total intake of water from *all* dietary sources is approximately 2 L per day for women and 2.5 L per day for men. This does *not* represent 2 L per day of drinking water; there is a widespread popular misconception that people need to drink 8 cups of water each day to meet their requirement. Most surveyed

TABLE 15-3

Total Water Intake (g/kcal/day) by Age and Sex[1–3]

				Percentile Distribution				
Sex	**Age (yr)**	**Mean**	**SD[4]**	**5**	**25**	**50**	**75**	**95**
Males	<1[5]	1.5	0.3	1.1	1.3	1.5	1.7	2.0
	1–10[5]	1.0	0.3	0.6	0.8	1.0	1.2	1.5
	11–19	1.0	0.3	0.6	0.8	0.9	1.1	1.5
	20–64	1.1	0.4	0.6	0.9	1.1	1.3	1.9
	65+	1.3	0.5	0.8	1.0	1.2	1.5	2.2
Females	<1[5]	1.6	0.6	1.0	1.3	1.5	1.7	2.1
	1–10[5]	1.0	0.3	0.6	0.8	1.0	1.1	1.5
	11–19[6]	1.1	0.4	0.6	0.8	1.0	1.2	1.8
	20–64[6]	1.4	0.9	0.7	1.0	1.3	1.7	2.6
	65+	1.5	0.6	0.8	1.1	1.4	1.8	2.6
Pregnant women		1.3	0.5	0.7	0.9	1.2	1.5	2.2
Lactating women		1.3	0.4	0.7	1.0	1.2	1.5	2.1

[1]Total water intake from all sources (drinking water, beverages, and foods).
[2]1 g = 1 mL water.
[3]Adapted from Ershow AG, Cantor KP analysis (3) based on data from 1977–1978 USDA Nationwide Food Consumption Survey.
[4]SD = Standard deviation.
[5]Does not include breast-fed children.
[6]Does not include pregnant or lactating women.

participants clearly have an adequate intake of water; more than half the population consumed more than the 1 mL/kcal requirement estimated to be adequate under most circumstances. Plain drinking water, tea, coffee, and carbonated beverages provide the largest fraction of all dietary water (Table 15-4); approximately one-fourth derives from solid foods and soups.

Pregnant and lactating women do consume more total water than their nonpregnant, nonlactating peers, but the extra intake is relatively small (ie, a daily increment of less than 2 cups) (4). The average water content of pregnant and lactating women's diets is 1.3 mL/kcal to 1.4 mL/kcal, similar to that of nonpregnant, nonlactating women of similar age (4, 5). Thus, diets accounting for the increased energy needs of these conditions will generally provide adequate water as well.

Tapwater (consumed as plain water or used to prepare tea, coffee, and other foods and beverages) provides 55 ± 18% (mean ± SD) of total water intake in freely selected diets (3). This figure varies little with season, geographic location, or age. The tapwater intake of infants (younger than 1 year) will reflect the type of formula they drink; tapwater intake is low when ready-to-feed formula is used, whereas tapwater intake composes nearly all the water intake of babies drinking powdered formula. For adults 20 years to 64 years, the average tapwater intake is 1,366 g/day, supplied primarily by plain drinking water (674 g), coffee (395 g), tea (152 g), cooked grain products (45 g), and reconstituted citrus juices (27 g).

Water and Beverage Intakes and Allowances for Controlled Diet Studies

Two main aspects of water and beverage intake should be assessed for participants in a research diet study: (1) what the usual daily total water intake is, and (2) what the typical daily pattern of beverage intake is. Daily water intake should be assessed to ensure that the conditions of the study, which may entail complete provision of all beverages as well as food, meet the participant's requirements. The typical pattern of beverage intake should be assessed to help the study design fit better with the participant's established daily routines.

Assessing Intake

Total water intake can be assessed readily in the context of a standard 24-hour recall, with two special considerations. First, extra questions must be added to elicit information on water consumed. This entails asking about plain drinking water from tap, water fountain, or bottled water sources, and about extra ice added to foods or beverages. The 24-hour recall must include all foods and beverages, including plain water, tea, coffee, and unflavored carbonated waters.

Second, the database used for nutrient calculations must include information about the water (ie, moisture) content of the food. With this information, the total daily water intake can be calculated along with other nutrients of interest.

Typical patterns of beverage intake can also be assessed as part of the diet history (ie, food record or food frequency

TABLE 15-4

Dietary Sources of Total Water Intake by Age (Both Sexes)[1]

Age (yr)	Source[4]	g/day[2] Mean	SD[5]	Percentile Distribution[3] 5	25	50	75	95	% of Total g/day Mean	SD
1[6]	Food	250	198	0	72	236	381	633	21	16
	Drinking Water	197	186	0	0	240	240	480	16	14
	Other Beverages	701	235	333	558	693	839	1,085	63	19
	All Sources	1,148	332	631	920	1,120	1,339	1,727	100	—
1–10[6]	Food	409	175	175	283	384	506	727	27	10
	Drinking Water	505	354	0	240	480	720	1,200	30	16
	Other Beverages	645	247	283	483	630	784	1,083	43	14
	All Sources	1,559	507	838	1,210	1,497	1,843	2,507	100	—
11–19[7]	Food	515	230	204	349	487	638	933	27	10
	Drinking Water	664	483	0	320	560	880	1,600	31	17
	Other Beverages	809	382	289	566	756	984	1,490	42	15
	All Sources	1,989	719	1,025	1,489	1,874	2,369	3,336	100	—
20–64[7]	Food	545	239	223	375	509	678	992	26	10
	Drinking Water	674	555	0	320	560	960	1,760	28	17
	Other Beverages	1,024	539	358	668	925	1,267	2,001	46	17
	All Sources	2,243	839	1,133	1,665	2,109	2,663	3,793	100	—
65+	Food	575	243	238	406	542	711	1,028	27	10
	Drinking Water	776	554	0	400	720	1,040	1,920	33	17
	Other Beverages	849	381	310	604	807	1,032	1,523	40	15
	All Sources	2,199	1,196	1,700	2,109	2,616	3,482	4,370	100	—

[1]Adapted from Ershow AG, Cantor KP analysis (3) based on data from 1977–1978 USDA Nationwide Food Consumption Survey.
[2]1 g = 1 mL water.
[3]Percentile values for all sources are independent of values for individual sources (food, drinking water, and other beverages).
[4]Food category includes soups.
[5]SD = Standard deviation.
[6]Does not include breast-fed children.
[7]Does not include pregnant or lactating women.
0 = <0.5 g/day

questionnaire). Many people have well-established daily patterns of fluid intake, most notably for tea, coffee, soda, juice, and plain water. Some people take several discrete coffee breaks; others keep a bottle of water or soda at hand from which they sip throughout the day. A feeding study that interrupts these patterns will be more burdensome for the participant. If the study requires switching to noncaloric sodas or caffeine-free beverages, the participant may have difficulty adapting. A list of acceptable alternatives should be provided to guide the individual in choosing beverages. In addition, explaining the rationale for the study requirements will ease the transition for most people.

Alcoholic beverage intake generally is underreported, and extra probing may be necessary to obtain accurate information. It may be helpful to supplement a 24-hour recall or typical day's intake questionnaire with some food frequency questions directed at weekly patterns of intake, with special emphasis on weekend days and on different types of beverages, such as wine, beer, and distilled liquors. Some of this information should be obtained as part of screening procedures because heavy habitual consumers of alcohol often are unsuitable as participants in controlled diet studies.

Estimating Allowances

As mentioned earlier, a basic water allowance can be set at 1.5 g/kcal, which falls between the 75th and 90th percentile of intake for males and the 50th and 75th percentile of intake for females. A practical approach is to set the allowance at the 75th percentile of intake and quickly adjust up or down depending on whether the participant considers the level too high or too low. The 75th percentile for adult men is 3,000 g/day, 39 g/kg/day, or 1.3 g/kcal/day; for adult women it is 2,400 g/day, 40 g/kg/day, or 1.7 g/kcal/day) (Tables 15-1 through 15-3).

Basing intake on body weight can be convenient because this unit often is used for calculation of other nutrient intakes. This value can be adjusted after obtaining information about the participant's own typical daily intake of water, level of physical activity at work and leisure, tendency to perspire, and whether the work environment is hot. Season

TABLE 15-5

Dietary Sources of Total Water Intake by Pregnant and Lactating Women[1]

		g/day[2]							% of Total g/day	
				Percentile Distribution[3]						
Age (yr)	Source[4]	Mean	SD[5]	5	25	50	75	95	Mean	SD
Pregnant	Food	483	214	191	323	455	612	867	25	11
	Drinking Water	695	525	0	320	640	960	1,760	32	19
	Other Beverages	897	497	274	546	820	1,130	1,818	44	17
	All Sources	2,076	743	1,085	1,553	1,928	2,444	3,475	100	—
Lactating	Food	558	268	254	382	499	678	1,175	25	9
	Drinking Water	677	492	0	240	560	1,040	1,600	29	18
	Other Beverages	1,008	512	307	719	913	1,215	1,885	46	18
	All Sources	2,243	658	1,185	1,833	2,164	2,658	3,353	100	—

[1]Adapted from Ershow AG, Cantor KP analysis (3) based on data from 1977–1978 USDA Nationwide Food Consumption Survey.
[2]1 g = 1 mL water.
[3]Percentile values for all sources are independent of values for individual sources (food, drinking water, and other beverages).
[4]Food category includes soups.
[5]SD = standard deviation.
0 = <0.5 g/day

of the year has a surprisingly small overall effect on water intake, because adults generally replace hot drinks with cold with the change in seasons.

The diuretic effects of coffee, tea, and alcohol must be considered when planners estimate the water allowance for protocols that do not permit *ad libitum* (ad lib) intake. Total water intake may need to be higher if these beverages are used rather than plain water, uncaffeinated drinks, and alcohol-free drinks.

Providing Water and Beverages in Controlled Diet Studies

Drinking Water

Some studies allow the participant to consume plain water ad lib, and neither the source nor the quantities consumed are of interest. For other studies, source and quantities must be tightly controlled. Participants can be given bottled water of known composition in half-liter or liter bottles to carry with them throughout the day. For studies allowing water ad lib, it is important to provide more than is needed so that the participant will not run out. One liter of plain water per day is sufficient for 75% of adults; 2 L per day will accommodate all but the heaviest consumers (this quantity does not include the water provided through foods and other beverages). Remembering that water weighs 1 kg (2.2 lb) per liter, it is important not to burden the person with unnecessary amounts to carry.

Mineral balance studies must use water with defined mineral content for drinking, food preparation, and ice. Distilled or deionized water is frequently used for this purpose. Distilled water can be purchased in liter bottles or a distilled water system can be installed in the research kitchen. Unfortunately, distilled or deionized waters taste flat and unappealing; having the water very cold can help participants accept the taste. Providing the water allowance as a flavored drink or with a small amount of lemon juice may be more appealing, but in this case all quantities must be consumed. Some commercial bottled waters may be sufficiently low in certain minerals that they can be used for such studies yet will taste better than distilled water. If bottled waters are used, however, they should be purchased in a single lot and the mineral content analyzed directly; compositional information from the label may not be accurate. Under these circumstances a considerable amount of storage space for water may be needed.

Other Beverages

The amounts and types of all beverages consumed in a research diet study must be defined as are all other foods. Some investigators allow ad lib consumption not only of plain water but also of unsweetened (''no-cal'') carbonated drinks, tea, and coffee. These would not affect caloric balance but may affect mineral intake. If the participant is accustomed to adding sugar, milk, or cream to beverages it often is possible within the context of the study to add part of the milk or sugar allowance to the coffee or tea; the contribution of these additives must then be considered in the nutrient calculation of the diet.

Tea and coffee consumption frequently is limited during research studies because of the effects of caffeine, but they also contain other biologically active substances. For example, coffee is a rich source of niacin and potassium (6); tea contains substantial amounts of fluoride (7). Both contain tannin that may affect mineral absorption (8). Simply switching to decaffeinated versions may not eliminate these effects.

Carbonated beverages must be defined for the purposes of the study. Some types of "seltzer" are not plain carbonated water but rather are sweetened with sugar or corn syrup. The investigators also must decide whether to allow caffeinated sodas and artificially sweetened sodas as free or restricted items.

According to 1994 USDA survey data, alcoholic beverages typically provide 2% to 4% of daily energy for adult males and 1% to 2% for adult females (9). These figures likely are general underestimates and some individuals consume much more than these amounts. Alcoholic beverages often are not allowed within controlled diet protocols because of their complex and poorly characterized chemical composition, effects on behavior, and potential confounding of metabolic phenomena. However alcohol-free beers are available and may provide an acceptable substitute in some situations.

Conclusion: Considerations for Protocol Design

Water and fluid allowances, sources, and intakes should be evaluated carefully for different types of well-controlled dietary studies.

- In studies using liquid formula diets, the formula is likely to provide the largest source of water. Attempting to dilute the formula in the entire day's water allotment, however, will lead to an overly large volume of formula. Calculating the participant's individual water allowance will permit the dietitian to determine the osmolality of the entire diet; known volumes of drinking water can be provided to supplement the amount taken in through the formula. (Also see Chapter 14, "Planning and Producing Formula Diets.")
- Excretion studies or balance studies entailing 24-hour urine collections gain in precision from exact knowledge of water intake. Completeness of collection can be estimated better if the previous day's water intake is known. Appropriate instructions and data collection forms must be provided to the participants for recording all beverages, water, and foods consumed within a specified time period. (Also see Chapter 17, "Energy Needs and Weight Maintenance in Controlled Diet Studies.")
- Mineral balance studies must account for minerals present in water, just as in any other part of the diet. Controlled feeding studies of blood pressure may also have a similar design requirement. Water of known composition must be provided and used not just for ad lib consumption but also in the preparation of all foods, beverages, and ice. Depending on study requirements, this water can be tapwater, deionized water, or bottled water. In trace mineral studies, deionized water should be used for washing dishes. Regardless of the source, the water must be chemically analyzed for mineral content. For example, some softened waters have a high sodium content. The volume of all consumed water must also be a defined quantity, as with all other foodstuffs. Enough water must be provided so that the participant will not resort to undefined sources such as drinking fountains or sink taps.
- Some protocols require that the individual produce urine samples at timed intervals. For these studies, the water intake pattern must be manipulated so that large boluses of water or fluids are consumed at specific times of the day, with enough lag time to allow for absorption and renal clearance.
- Many protocols allow ad lib intake of tapwater but require that all other fluids and beverages be controlled. Tea, coffee, milk, juice, soups, and carbonated beverages are most likely to be regulated in this way.
- Well-accepted research diets are designed by considering typical patterns of intake for water and beverages, as well as for other foods. Portion sizes should resemble those frequently consumed by free-living individuals of similar body weight.

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