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**Chapter 3 - Water Ingestion**

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**3 INGESTION OF WATER AND OTHER SELECT LIQUIDS****3.1 INTRODUCTION**

Water ingestion can be a pathway of exposure to environmental chemicals among children. Contamination of water may occur at the water supply source (ground water or surface water); during treatment (for example toxic by-products may be formed during chlorination); or post-treatment (such as leaching of lead or other materials from plumbing systems). Children may be exposed to contaminants in water when consuming water directly as a beverage, indirectly from foods and drinks made with water, or incidentally while swimming. Estimating the magnitude of the potential dose of toxics from water ingestion requires information on the quantity of water consumed. The purpose of this section is to describe key and relevant published studies that provide information on water ingestion among children and to provide recommended ingestion rate values for use in exposure assessments. The studies described in this section provide information on ingestion of water consumed as a beverage, ingestion of other select liquids, and ingestion of water while swimming.

Currently, the U.S. EPA uses the quantity 1 L per day for infants (individuals of 10 kg body mass or less) and children as a default drinking water ingestion rate (U.S. EPA, 2000). This rate includes water consumed in the form of juices and other beverages containing tapwater. The National Academy of Sciences (NAS, 1977) estimated that daily consumption of water may vary with levels of physical activity and fluctuations in temperature and humidity. It is reasonable to assume that children engaging in physically-demanding activities or living in warmer regions may have higher levels of water ingestion. However, there is limited information on the effects of activity level and climatic conditions on water ingestion.

Various studies cited in this section have generated data on water ingestion rates; in general, these sources support U.S. EPA's use of 1 L/day as an upper-percentile tapwater ingestion rate for children under 10 years of age. Based on the applicability of the survey design to exposure assessments of the entire US population, the study by Khan and Stralka (2008) was selected as a key study of drinking water ingestion. In this study, ingestion rates for direct and indirect ingestion of water are reported. *Direct ingestion* is defined as direct consumption of water as a beverage, while *indirect ingestion* includes water added during food preparation, but not water intrinsic to purchased

foods (i.e. water that is naturally contained in foods) (Kahn and Stralka, 2008). Data for consumption of water from various sources (i.e., the community water supply, bottled water, and other sources) are also presented. For the purposes of exposure assessments involving site-specific contaminated drinking water, ingestion rates based on the community supply are most appropriate. Given the assumption that bottled water, and purchased foods and beverages that contain water are widely distributed and less likely to contain source-specific water, the use of total water ingestion rates may overestimate the potential exposure to toxic substances present only in local water supplies; therefore, tapwater ingestion of community water, rather than total water ingestion, is emphasized in this section.

The studies on water ingestion that are currently available are based on short-term survey data (two days). Although short-term data may be suitable for obtaining mean or median ingestion values that are representative of both short- and long-term ingestion distributions, upper and lower -percentile values may be different for short-term and long-term data. It should also be noted that most currently available water ingestion surveys are based on recall. This may be a source of uncertainty in the estimated ingestion rates because of the subjective nature of this type of survey technique. Percentile distributions for water ingestion are presented in this handbook, where sufficient data are available. Data were not available to estimate drinking water ingestion rates for children during high activity levels or in extreme climates (i.e., hot weather). Also, data are not provided for the location of water consumption (i.e., home, school, day care center, etc.).

Limited information was available regarding children's incidental ingestion of water while swimming. This exposure pathway may be important since children are likely to ingest larger volumes of water while swimming compared to adults; and therefore, may have a greater exposure to pathogenic microorganisms and chemicals present in the water than adults. A recent pilot study (Dufour et al., 2006) has provided some quantitative experimental data on water ingestion for child and adult swimmers. These data are provided in this chapter.

The recommendations for water ingestion rates are provided in the next section, along with a summary of the confidence ratings for these recommendations. The recommended values are based on the key study identified by U.S. EPA for this factor. Following the recommendations, the key study on



water ingestion is summarized. Relevant data on ingestion of water and other select liquids are also provided. These studies are presented to provide the reader with added perspective on the current state-of-knowledge pertaining to ingestion of water and select liquids.

### **3.2 RECOMMENDATIONS**

#### **3.2.1 Water Ingestion from Consumption of Water as a Beverage and from Food and Drink**

The recommended water ingestion rates for children are based on Kahn and Stralka (2008 and supplementary data). This study presents estimates of water ingestion by age range categories for the population of the United States using data collected in the U.S. Department of Agriculture's (USDA's) 1994-96 and 1998 Continuing Survey of Food Intakes by Individuals (CSFII) (USDA, 1998). A summary of the recommended values for water ingestion rates is presented in Table 3-1. A characterization of the overall confidence in the accuracy and appropriateness of the recommendations for drinking water intake is presented in Table 3-2.

#### **3.2.2 Water Ingestion while Swimming**

Based on the results of the Dufour et al. (2006) study, a mean water ingestion rate of 50 mL/hour for children ages 6 to 15 years is recommended for exposure scenarios involving swimming activities. The recommended upper percentile value is 100 mL/hour. The recommended values for children between 18 and 21 years of age are based on the results for adults from Dufour et al. (2006). The mean value is 20 mL/hour and the upper percentile value is 70 mL/hour. Although this estimate was derived from swimming pool experiments, Dufour et al. (2006) noted that swimming behavior of pool swimmers may be similar to freshwater swimmers. Estimates may be different for salt water swimmers. The confidence ratings for these recommendations are presented in Table 3-3. Data on the amount of time spent swimming can be found in chapter 16, Table 16-21.



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Table 3-1. Recommended Values for Drinking Water Ingestion Rates <sup>a</sup>								
Age Group	Mean		95 <sup>th</sup> Percentile		Multiple Percentiles	Source		
	mL/day	mL/kg-day	mL/day	mL/kg-day				
Per Capita								
Birth to <1 month	184	52	839 <sup>b</sup>	232 <sup>b</sup>				
1 to <3 months	227	48	896 <sup>b</sup>	205 <sup>b</sup>				
3 to <6 months	362	52	1,056	159				
6 to <12 months	360	41	1,055	126				
1 to <2 years	271	23	837	71	See Tables 3-4 and 3-9	Kahn and Stralka (2008)		
2 to <3 years	317	23	877	60				
3 to <6 years	380	22	1,078	61				
6 to <11 years	447	16	1,235	43				
11 to <16 years	606	12	1,727	34				
16 to <18 years	731	11	1,983 <sup>b</sup>	31 <sup>b</sup>				
18 to <21 years	826	12	2,540 <sup>b</sup>	35 <sup>b</sup>				
Consumers Only								
Birth to <1 month	470 <sup>b</sup>	137 <sup>b</sup>	858 <sup>b</sup>	238 <sup>b</sup>				
1 to <3 months	552	119	1,053 <sup>b</sup>	285 <sup>b</sup>				
3 to <6 months	556	80	1,171 <sup>b</sup>	173 <sup>b</sup>				
6 to <12 months	467	53	1,147	129				
1 to <2 years	308	27	893	75	See Tables 3-14 and 3-19	Kahn and Stralka (2008)		
2 to <3 years	356	26	912	62				
3 to <6 years	417	24	1,099	65				
6 to <11 years	480	17	1,251	45				
11 to <16 years	652	13	1,744	34				
16 to <18 years	792	12	2,002 <sup>b</sup>	32 <sup>b</sup>				
18 to <21 years	895	13	2,565 <sup>b</sup>	35 <sup>b</sup>				
<sup>a</sup> Ingestion rates for combined direct and indirect water from community water supply. <sup>b</sup> The sample size does not meet minimum requirements as described in the "Third Report on Nutrition Monitoring in the United States" (LSRO, 1995).								



Table 3-2. Confidence in Recommendations for Drinking Water Ingestion Rates

General Assessment Factors	Rationale	Rating
<p><b>Soundness</b></p> <p><i>Adequacy of Approach</i></p> <p><i>Minimal (or defined) Bias</i></p>	<p>The survey methodology and data analysis was adequate. The survey sampled approximately 10,000 individuals under the age of 21 years; sample size varied with age.</p> <p>No physical measurements were taken. The method relied on recent recall of standardized volumes of drinking water containers.</p>	Medium to High
<p><b>Applicability and Utility</b></p> <p><i>Exposure Factor of Interest</i></p> <p><i>Representativeness</i></p> <p><i>Currency</i></p> <p><i>Data Collection Period</i></p>	<p>The key study was directly relevant to water ingestion.</p> <p>The data were demographically representative (based on stratified random sample).</p> <p>Data were collected between 1994 and 1998.</p> <p>Data were collected for two non-consecutive days. However, long term variability may be small. Use of a short-term average as a chronic ingestion measure can be assumed.</p>	Medium to High
<p><b>Clarity and Completeness</b></p> <p><i>Accessibility</i></p> <p><i>Reproducibility</i></p> <p><i>Quality Assurance</i></p>	<p>The CSFII data are publicly available. The Kahn and Stralka (2008) analysis of the CSFII 1994-96, 1998 data was published in a peer-reviewed journal.</p> <p>The methodology was clearly presented; enough information was included to reproduce the results.</p> <p>Quality assurance of the CSFII data was good; quality control of the secondary data analysis was not well described.</p>	High
<p><b>Variability and Uncertainty</b></p> <p><i>Variability in Population</i></p> <p><i>Uncertainty</i></p>	<p>Full distributions were given in a separate document (Khan and Stralka, 2008b).</p> <p>Except for data collection based on recall, sources of uncertainty were minimal.</p>	High
<p><b>Evaluation and Review</b></p> <p><i>Peer Review</i></p> <p><i>Number and Agreement of Studies</i></p>	<p>The USDA CSFII survey received high level of peer review. The Kahn and Stralka (2008) study was published in a peer-reviewed journal.</p> <p>There was 1 key study for drinking water ingestion.</p>	Medium
<b>Overall Rating</b>		<b>Medium to High</b>





Table 3-3. Confidence in Recommendations for Water Ingestion while Swimming		
General Assessment Factors	Rationale	Rating
<b>Soundness</b>		Medium
<i>Adequacy of Approach</i>	The approach appears to be appropriate given that cyanuric acid (a tracer used in treated pool water) is not metabolized, but the sample size was small (41 children). The Dufour et al. (2006) study analyzed primary data on water ingestion during swimming.	
<i>Minimal (or defined) Bias</i>	Data were collected over a period of 45 minutes; this may not accurately reflect the time spent by a recreational swimmer.	
<b>Applicability and Utility</b>		Low to Medium
<i>Exposure Factor of Interest</i>	The key study was directly relevant to water ingestion while swimming.	
<i>Representativeness</i>	The sample was not representative of the U.S. population. Data cannot be broken out by age categories	
<i>Currency</i>	It appears that the study was conducted in 2005.	
<i>Data Collection Period</i>	Data were collected over a period of 45 minutes.	
<b>Clarity and Completeness</b>		Medium
<i>Accessibility</i>	The Dufour et al. (2006) study was published in a peer-reviewed journal.	
<i>Reproducibility</i>	The methodology was clearly presented; enough information was included to reproduce the results..	
<i>Quality Assurance</i>	Quality assurance methods were not described in the study.	
<b>Variability and Uncertainty</b>		Low
<i>Variability in Population</i>	Only mean values for water ingestion were provided. Data were not broken out by age groups	
<i>Uncertainty</i>	There were multiple sources of uncertainty (e.g., sample population may not reflect swimming practices for all swimmers, rates based on swimming duration of 45 minutes, differences by age group not defined).	
<b>Evaluation and Review</b>		Medium
<i>Peer Review</i>	Dufour et al. (2006) was published in a peer-reviewed journal.	
<i>Number and Agreement of Studies</i>	There was 1 study for ingestion of water when swimming.	
<b>Overall Rating</b>		Low



### **3.3 DRINKING WATER INGESTION STUDIES**

#### **3.3.1 Key Drinking Water Ingestion Study**

##### **3.3.1.1 *Kahn and Stralka, 2008 - Estimated Daily Average Per Capita Water Ingestion by Child and Adult Age Categories Based on USDA's 1994-96 and 1998 Continuing Survey of Food Intakes by Individuals***

Kahn and Stralka (2008) analyzed the combined 1994-96 and 1998 Continuing Survey of Food Intakes by Individuals (CSFII) data sets to examine water ingestion rates of adults and children. USDA surveyed households in the United States and District of Columbia and collected food and beverage recall data as part of the CSFII (USDA, 1998). In the initial 1994-96 survey, over 15,000 respondents provided data on what they ate and drank over two non-consecutive days. A 1998 supplement, using the same methodology, added responses for approximately 5,000 children aged 9 years and younger to the database. Of the more than 20,000 individuals surveyed, approximately 10,000 were under 21 years of age, and approximately 9,000 were under the age of 11. For both survey days, data were collected by an in-home interviewer. The day two interview was conducted 3 to 10 days later and on a different day of the week. The 1994-96 survey and 1998 supplement are referred to collectively as CSFII 1994-96, 1998. Each individual in the survey was assigned a sample weight based on his or her demographic data. These weights were taken into account when calculating mean and percentile water ingestion rates from various sources.

Khan and Stralka (2008) derived mean and percentile estimates of daily average water ingestion for children in eleven different age categories: <1 month, 1 to <3 months, 3 to <6 months, 6 to <12 months, 1 to <2 years of age, 2 to <3 years, 3 to <6 years, 6 to <11 years, 11 to <16 years, 16 to <18 years, and 18 to <21 years of age. The increased sample size for children younger than 11 years of age (from 4,339 in the initial 1994-96 survey to 9,643 children in the combined 1994-96, 1998 survey) enabled water ingestion estimates to be categorized into the finer age categories recommended by U.S. EPA (2005). Per capita and consumers only water ingestion estimates were reported in the Kahn and Stralka (2008) study for two water source categories: all sources and community water. "All sources" included water from all supply sources such as community water supply

(i.e., tap water), bottled water, other sources, and missing sources. "Community water" included tap water from a community or municipal water supply. Other sources included wells, springs, and cisterns; missing sources represented water sources that the survey respondent was unable to identify. The water ingestion estimates included both water ingested directly as a beverage (direct water) and water added to foods and beverages during final preparation at home or by local food service establishments such as school cafeterias and restaurants (indirect water). Commercial water added by a manufacturer (i.e., water contained in soda or beer) and intrinsic water in foods and liquids (i.e., milk and natural undiluted juice) were not included in the estimates. Kahn and Stralka (2008) only reported the mean, 90<sup>th</sup> and 95<sup>th</sup> percentile estimates of per capita and consumers only ingestion. The full distribution of ingestion estimates for various water source categories (all sources, community water, bottled water, and other sources) were provided by the author. Tables 3-4 to 3-7 provide mean and percentile per capita ingestion estimates of total water (combined direct and indirect water) in mL/day for the various water source categories (i.e., community, bottled, other, and all sources). The 90 percent confidence intervals around the estimated means and the 90 percent bootstrap intervals around the 90<sup>th</sup> and 95<sup>th</sup> percentiles of total water ingestion from all water sources are presented in Table 3-8. Tables 3-9 to 3-13 present the same information as Tables 3-4 to 3-8 but in units of mL/kg-day. Consumers only combined direct and indirect water ingestion estimates in mL/day for the various source categories are provided in Tables 3-14 to 3-17. Table 3-18 presents confidence and bootstrap intervals for total water ingestion estimates by consumers only from all sources. Tables 3-19 to 3-23 present the same information as Tables 3-14 to 3-18 but in units of mL/kg-day.

The data show that the total quantity of water ingested per unit mass of body weight is at a maximum in the first month of life and decreases with increasing age. The per capita ingestion rate of water from all sources combined for children under 1 month of age is approximately four times higher than that adults, and consumers younger than 1 month of age ingest approximately 8 times the amount of water (all sources combined) as adults (Kahn and Stralka, 2008). The pattern of decreasing water ingestion per unit of body weight is also observed in per capita and consumers only estimates of community water (Tables 3-9 and 3-



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19), bottled water (Table 3-10 and 3-20) and other sources (Tables 3-11 and 3-21).

The CSFII 1994-96, 1998 data have both strengths and limitations with regard to estimating water ingestion. These are discussed in detail in U.S. EPA (2004) and Kahn and Stralka (2008). The principal advantages of this survey are (1) that the survey was designed to obtain a statistically valid sample of the entire United States population that included children and low income groups; (2) sample weights were provided that facilitated proper analysis of the data and accounted for non-response; and (3) that the sample size (approximately 10,000 children) is sufficient to allow categorization within narrowly defined age categories. Over sampling of children enhanced the precision and accuracy of the estimates for the child population subsets. One limitation of this survey is that data were collected for only 2 days and does not necessarily represent “usual intake.” “Usual dietary intake” refers to the long-term average of daily intakes by an individual. Thus, upper percentile water ingestion estimates based on short-term data may differ from long-term rates because short-term consumption data tend to be inherently more variable. However, Kahn and Stralka (2008) noted that variability due to short term duration of the survey does not result in bias of estimates of overall mean. In addition, the survey was conducted on non-consecutive days, which improves the variance over consecutive days of consumption. However, the two non-consecutive days of data collection, although an advantage over two consecutive days, provide limited information on individual respondents. The two-day mean for an individual can easily be skewed for numerous reasons. Estimation at the individual respondent level was not, however, an objective of the survey. The large sample provides useful information on the overall distribution of ingestion by the population, and should adequately reflect the range among respondent variability. Another limitation of these data is that the survey design, while being well-tailored for the overall population of the United States and conducted throughout the year to account for seasonal variation, is of limited utility for assessing small and potentially at-risk subpopulations based on ethnicity, medical status, geography/climate, or other factors such as activity level.

**3.3.2 Relevant Drinking Water Ingestion Studies****3.3.2.1 Levy et al., 1995 - Infant Fluoride Intake From Drinking Water Added to Formula, Beverages, and Food**

Levy et al. (1995) conducted a study to determine fluoride intake by infants through drinking water and other beverages prepared with water and baby foods. The study was longitudinal and covered the ages from birth to 9 months old. A total of 192 mothers, recruited from the *post partum* wards of two hospitals in Iowa City, completed mail questionnaires and three-day beverage and food diaries for their infants at ages 6 weeks, and 3, 6, and 9 months of age (Levy et al., 1995). The questionnaire addressed feeding habits, water sources and ingestion, and the use of dietary fluoride supplements during the preceding week (Levy et al., 1995). Data on the quantity of water consumed by itself or as an additive to infant formula, other beverages, or foods were obtained. In addition, the questionnaire addressed the infants’ ingestion of cow’s milk, breast-milk, ready-to-feed infant products (formula, juices, beverages, baby food), and table foods.

Mothers were contacted for any clarifications of missing data and discrepancies (Levy et al., 1995). Levy et al. (1995) assessed non-response bias and found no significant differences in the reported number of adults or children in the family, water sources, or family income at 3, 6, or 9 months. Table 3-24 provides the range of water ingestion from water by itself and from addition to selected foods and beverages. The percentage of infants ingesting water by itself increased from 28 percent at 6 weeks to 66 percent at 9 months, respectively, and the mean intake increased slightly over this time frame. During this time frame, the largest proportion of the infants’ water ingestion (i.e., 36 percent at 9 months to 48 percent at 6 months) came from the addition of water to formula. Levy et al. (1995) noted that 32 percent of the infants at age 6 weeks and 23 percent of the infants at age 3 months did not receive any water from any of the sources studied. Levy et al. (1995) also noted that the proportion of children ingesting some water from all sources gradually increased with age.

The advantages of this study are that it provides information on water ingestion of infants starting at 6 weeks old and the data are for water only and for water added to beverages and foods. The limitations of the study are that the sample size was small for each age group, it captured information from a select geographical location, and data were collected through self reporting. The authors noted, however,



that the three-day diary has been shown to be a valid assessment tool. Levy et al. (1995) also stated that (1) for each time period, the ages of the infants varied by a few days to a few weeks, and are, therefore, not exact and could, at early ages, have an effect on age-specific intake patterns, and (2) the same number of infants were not available at each of the four time periods.

**3.3.2.2 Heller et al., 2000 - Water Consumption and Nursing Characteristics of Infants by Race and Ethnicity**

Heller et al. (2000) analyzed data from the 1994-96 CSFII to evaluate racial/ethnic differences in the ingestion rates of water in children younger than 2 years old. Using data from 946 children in this age group, the mean amounts of water consumed from eight sources were determined for various racial/ethnic groups, including black non-Hispanic, white non-Hispanic, Hispanic and "other" (Asian, Pacific Islander, American Indian, Alaskan Native, and other non-specified racial/ethnic groups). The sources analyzed included: (1) plain tap water, (2) milk and milk drinks, (3) reconstituted powdered or liquid infant formula made from drinking water, (4) ready-to-feed and other infant formula, (5) baby food, (6) carbonated beverages, (7) fruit and vegetable juices and other noncarbonated drinks, and (8) other foods and beverages. In addition, Heller et al. (2000) calculated mean plain water and total water ingestion rates for children by age, sex, region, urbanicity, and poverty category. Ages were defined as less than 12 months and 12 to 24 months. Region was categorized as Northeast, Midwest, South, and West. The states represented by each of these regions was not reported in Heller et al. (2000). However, it is likely that these regions were defined in the same way as in Sohn et al. (2001). See Section 3.3.2.4 for a discussion on the Sohn et al. (2001) study. Urbanicity of the residence was defined as urban (i.e., being in a Metropolitan Statistical Area [MSA], suburban [outside of an MSA], or rural [being in a non-MSA]). Poverty category was derived from the poverty income ratio. In this study, a poverty income ratio was calculated by dividing the family's annual income by the federal poverty threshold for that size household. The poverty categories used were 0-1.30, 1.31-3.50, and greater than 3.50 times the federal poverty level (Heller et al., 2000).

Table 3-25 provides water ingestion estimates for the eight water sources evaluated, for each of the

race/ethnic groups. Heller et al. (2000) reported that black non-Hispanic children had the highest mean plain tap water intake (21.3 mL/kg-day), and white non-Hispanic children had the lowest mean plain tap water intake (12.7 mL/kg-day). The only statistically significant difference between the racial/ethnic groups was found to be in plain tap water consumption and total water consumption. Reconstituted baby formula made up the highest proportion of total water intake for all race/ethnic groups. Table 3-26 presents tap water and total water ingestion by age, sex, region, urbanicity, and poverty category. On average, children younger than 12 months of age consumed less plain tap water (11.0 mL/kg-day) than children aged 12-24 months (17.7 mL/kg-day). There were no significant differences in plain tap water consumption by sex, region, or urbanicity. Heller et al. (2000) reported a significant association between higher income and lower plain tap water consumption. For total water consumption, ingestion per kg body weight was lower for the 12-24-month-old children than for those younger than 12 months of age. Urban children consumed more plain tap water and total water than suburban and rural children. In addition, plain tap water and total water ingestion was found to decrease with increasing poverty category (i.e., higher wealth).

A major strength of the Heller et al. (2000) study is that it provides information on tap water and total water consumption by race, age, sex, region, urbanicity, and family income. The weaknesses in the CSFII data set have been discussed under Kahn and Stralka (2008) and U.S. EPA (2004) and include surveying participants for only two days.

**3.3.2.3 Sichert-Hellert et al., 2001 - Fifteen Year Trends in Water Intake in German Children and Adolescents: Results of the DONALD Study**

Water and beverage consumption was evaluated by Sichert-Hellert et al. (2001) using 3-day dietary records of 733 children, ages 2 to 13 years, enrolled in the Dortmund Nutritional and Anthropometric Longitudinally Designed Study (DONALD study). The DONALD study is a cohort study, conducted in Germany, that collects data on diet, metabolism, growth and development from healthy subjects between infancy and adulthood (Sichert-Hellert et al., 2001). Beginning in 1985, approximately 40 to 50 infants were enrolled in the study annually. Mothers of the participants were



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recruited in hospital maternity wards. Older children and parents of younger children were asked to keep dietary records for three days by recording and weighing (to the nearest 1 gram) all foods and fluids, including water, consumed.

Sichert-Hellert et al. (2001) evaluated 3,736 dietary records from 733 subjects (354 males and 379 females) collected between 1985 and 1999. Total water ingestion was defined as the sum of water content from food (intrinsic water), beverages and oxidation. Beverages included milk, mineral water, tap water, juice, soft drinks, and coffee and tea. Table 3-27 presents the mean water ingestion rates for these different sources, as well as mean total water ingestion rates for three age ranges of children (age 2 to 3 years, age 4 to 8 years, and age 9 to 13 years). According to Sichert-Hellert et al. (2001), mean total water ingestion increased with age from 1,114 mL/day in the 2 to 3 year old subjects to 1,891 and 1,676 mL/day in 9 to 13-year-old boys and girls, respectively. However, mean total water intake per body weight decreased with age. Sichert-Hellert et al. (2001) observed that the most important source of total water ingestion was mineral water for all children, except the 2 to 3 year olds. For these children, the most important source of total water ingestion was milk.

One of the limitations of this study is that it evaluated water and beverage consumption in German children and, as such, it may not be representative of consumption patterns of U.S. children.

### **3.3.2.4 Sohn et al., 2001 - Fluid Consumption Related to Climate Among Children in the United States**

Sohn et al. (2001) investigated the relationship between fluid consumption among children aged 1 to 10 years and local climate using data from the third National Health and Nutrition Examination Survey (NHANES III, 1988-94). Children aged 1 to 10 years who completed the 24-hour dietary interview (or proxy interview for the younger children) during the NHANES III survey were selected for the analysis. Breast-fed children were excluded from the analysis. Among 8,613 children who were surveyed, 688 (18 percent) were excluded due to incomplete data. A total of 7,925 eligible children remained. Since data for climatic conditions were not collected in the NHANES III survey, the mean daily maximum temperature from 1961 to 1990, averaged for the month during which the NHANES III survey was conducted, was obtained for each survey

location from the U.S. Local Climate Historical Database. Of the 7,925 eligible children with complete dietary data, temperature information was derived for only 3,869 children (48.8 percent) since detailed information on survey location, in terms of county and state, was released only for counties with a population of more than a half million.

Sohn et al. (2001) calculated the total amount of fluid intake for each child by adding the fluid intake from plain drinking water and the fluid intake from foods and beverages other than plain drinking water provided by NHANES III. Sohn et al. (2001) identified major fluid sources as milk (and milk drinks), juice (fruit and vegetable juices and other noncarbonated drinks), carbonated drinks, and plain water. Fluid intake from sources other than these major sources were all grouped into other foods and beverages. Other foods and beverages included bottled water, coffee, tea, baby food, soup, water-based beverages, and water used for dilution of food. Mean fluid ingestion rates of selected fluids for the total sample population and for the subsets of the sample population with and without temperature information are presented in Table 3-28. The estimated mean total fluid and plain water ingestion rates for the 3,869 children for whom temperature information was obtained are presented in Table 3-29 according to age (years), sex, race/ethnicity, poverty/income ratio, region, and urban or rural. Poverty/income ratio was defined as the ratio of the reported family income to the federal poverty level. The following categories were assigned: low socioeconomic status (SES) = 0.000-1.300 times the poverty/income ratio; medium SES = 1.3.01-3.500 times the poverty/income level; and high SES = 3.501 or greater times the poverty/income level. Regions were as Northeast, Midwest, South, and West, as defined by the U.S. Census (see Table 3-29). Sohn et al. (2001) did not find significant association between mean daily maximum temperature and total fluid or plain water ingestion, either before or after controlling for sex, age, SES and race or ethnicity. However, significant associations between fluid ingestion and age, sex, socioeconomic status and race and ethnicity were reported.

The main strength of the Sohn et al. (2001) study is the evaluation of water intake as it relates to weather data. The main limitations of this study were that northeast and western regions were over represented since temperature data was only available for counties with populations in excess of a half



million. In addition, whites were under-represented compared to other racial or ethnic groups. Other limitations include lack of data for children from extremely cold or hot weather conditions.

**3.3.2.5 Hilbig et al., 2002 - Measured Consumption of Tap Water in German Infants and Young Children as Background for Potential Health Risk Assessment: Data of the DONALD Study**

Hilbig et al. (2002) estimated tap water ingestion rates based on 3-day dietary records of 504 German children aged 3, 6, 9, 12, 18, 24 and 36 months. The data were collected between 1990 and 1998 as part of the DONALD study. Details of data collection for the DONALD study have been provided previously under the Sichert-Hellert et al. (2001) study in Section 3.3.2.3 of this handbook. Tap water ingestion rates were calculated for three subgroups of children: (1) breast-fed infants  $\leq 12$  months of age (exclusive and partial breast-fed infants) (2) formula-fed infants  $\leq 12$  months of age (no human milk, but including weaning food) and (3) mixed-fed young children aged 18 to 36 months. Hilbig et al. (2002) defined “total tap water from household” as water from the tap consumed as a beverage or used in food preparation. “Tap water from food manufacturing” was defined as water used in industrial production of foods, and “Total Tap Water” was defined as tap water consumed from both the household and that used in manufacturing.

Table 3-30 summarizes total tap water ingestion (in mL/day and mL/kg-day) and tap water ingestion from household and manufacturing sources (in mL/kg-day) for breastfed, formula fed and mixed-fed children. Mean total tap water intake was higher in formula-fed infants (53 mL/kg-day) than in breast-fed infants (17 g/kg-day) and mixed-fed young children (19 g/kg-day). Tap water from household sources constituted 66 to 97 percent of total tap water ingestion in the different age groups.

The major limitation of this study is that the study sample consists of families from an upper social background in Germany (Hilbig et al., 2002). Because the study was conducted in Germany, the data may not be directly applicable to the U.S. population.

**3.3.2.6 Marshall et al., 2003a - Patterns of Beverage Consumption During the Transition Stage of Infant Nutrition**

Marshall et al. (2003a) investigated beverage ingestion during the transition stage of infant nutrition. Mean ingestion of infant formula, cow’s milk, combined juice and juice drinks, water, and other beverages were estimated using a frequency questionnaire. A total of 701 children, ages six months through 24 months, participated in the Iowa Fluoride Study (IFS). Mothers of newborns were recruited from 1992 through 1995. The parents were sent questionnaires when the children were 6, 9, 12, 16, 20, and 24 months old. Of the 701 children, 470 returned all six questionnaires, 162 returned five, 58 returned four and 11 returned three, with the minimum criteria being three questionnaires to be included in the data set (Marshall et al., 2003a). The questionnaire was designed to assess the type and quantity of the beverages consumed during the previous week. The validity of the questionnaire was assessed using a three-day food diary for reference (Marshall et al., 2003a). The percentage of subjects consuming beverages and mean daily beverage ingestion for children with returned questionnaires are presented in Table 3-31. Human milk ingestion was not quantified, but the percent of children consuming human milk was provided at each age category (Table 3-31). Juice (100 percent) and juice drinks were not distinguished separately, but categorized as juice and juice drinks. Water used to dilute beverages beyond normal dilution and water consumed alone were combined. Based on Table 3-31, 97 percent of the children consumed human milk, formula, or cow’s milk throughout the study period, and the percentage of infants consuming human milk decreased with age, while the percent consuming water increased (Marshall et al., 2003a). Marshall et al. (2003a) observed that in general, lower family incomes were associated with less breastfeeding and increased ingestion of other beverages.

The advantage of this study is that it provides mean ingestion data for various beverages. Limitations of the study are that it is based on samples gathered in one geographical area and may not be reflective of the general population. The authors also noted the following limitations: the parents were not asked to differentiate between 100 percent juice and juice drinks; the data are parent-reported and could reflect perceptions of appropriate ingestion instead of actual ingestion, and a substantial



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number of the infants from well educated, economically secure households dropped out during the initial phase.

**3.3.2.7 Marshall et al., 2003b - Relative Validation of a Beverage Frequency Questionnaire in Children Ages 6 Months through 5 Years Using 3-day Food and Beverage Diaries**

This study was based on data taken from 700 children in the IFS. This study compared estimated beverage ingestion rates reported in questionnaires for the preceding week and dairies for the following week. Packets were sent periodically (every 4 to 6 months) to parents of children aged 6 weeks through 5 years of age. This study analyzed data from children, ages 6 and 12 months, and 2 and 5 years of age. Beverages were categorized as human milk, infant formula, cow's milk, juice and juice drinks, carbonated and rehydration beverages, prepared drinks (from powder) and water. The beverage questionnaire was completed by parents and summarized the average amount of each beverage consumed per day by their children. The data collection for the diaries maintained by parents included 1 weekend day and 2 week days and included detailed information about beverages consumed. Table 3-32 presents the mean ingestion rates of all beverages for children aged 6 and 12 months and 3 and 5 years. Marshall et al. (2003b) concluded that estimates of beverage ingestion derived from quantitative questionnaires are similar to those derived from diaries. They found that it is particularly useful to estimate ingestion of beverages consumed frequently using quantitative questionnaires.

The advantage of this study is that the survey was conducted in two different forms (questionnaire and diary) and that diaries for recording beverage ingestion were maintained by parents for three days. The main limitation is the lack of information regarding whether the diaries were populated on consecutive or non-consecutive days. The IFS survey participants may not be representative of the general population of the U.S. since participants were primarily white, and from affluent and well-educated families in one geographic region of the country.

**3.3.2.8 Skinner et al., 2004 - Transition in Infants' and Toddlers' Beverage Patterns**

Skinner et al. (2004) investigated the pattern of beverage consumption by infants and children participating in the Feeding Infant and Toddlers Study (FITS) sponsored by Gerber Products Company. The

FITS is a cross-sectional study designed to collect and analyze data on feeding practices, food consumption, and usual nutrient intake of U.S. infants and toddlers (Devaney et al., 2004). It included a stratified random sample of 3,022 infants and toddlers between 4 and 24 months of age. Parents or primary caregivers of sampled infants and toddlers completed a single 24-hour dietary recall of all foods and beverages consumed by the child on the previous day by telephone interview. All recalls were completed between March and July 2002. Detailed information on data collection, coding and analyses related to FITS are provided in Devaney et al. (2004).

Beverages consumed by FITS participants were identified as total milks (i.e., human milk, infant formulas, cows milk, soy milk, goat milk), 100 percent juices, fruit drinks, carbonated beverages, water and "other" drinks (i.e., tea, cocoa, dry milk mixtures, and electrolyte replacement beverages). There were six age groupings in the FITS study: 4 to 6, 7 to 8, 9 to 11, 12 to 14, 15 to 18, and 19 to 24 months. Skinner et al. (2004) calculated the percentage of children in each age group consuming any amount in a beverage category and the mean amounts consumed. Table 3-33 provides the mean beverage consumption rates in mL/day for the six age categories. Skinner et al. (2004) found that some form of milk beverage was consumed by almost all children at each age; however, total milk ingestion decreased with increasing age. Water consumption also doubled with age, from 163 mL/day in children aged 4 to 6 months old to 337 mL/day at 19 to 24 months old. The percentages of children consuming water increased from 34 percent at 4 to 6 months of age to 77 percent at 19 to 24 months of age.

A major strength of the Skinner et al. (2004) study is the large sample size (3,022 children). However, beverage ingestion estimates are based on one day of dietary recall data and human milk quantity derived from studies that weighed infants before and after each feeding to determine the quantity of human milk consumed (Devaney et al., 2004); therefore, estimates of total milk ingestion may not be accurate.

**3.4 WATER INGESTION WHILE SWIMMING**

**3.4.1 Dufour et al., 2006 - Water Ingestion During Swimming Activities in a Pool: A Pilot Study**

Dufour et al. (2006) estimated the amount of water ingested while swimming, using cyanuric acid as



an indicator of pool water ingestion exposure. Cyanuric acid is a breakdown product of chloroisocyanates which are commonly used as disinfectant stabilizers in recreational water treatment. Because ingested cyanuric acid passes through the body unmetabolized, the volume of water ingested can be estimated based on the amount of cyanuric acid measured in the pool water and in the urine of swimmers, as follows:

$$V_{\text{pool water ingested}} = V_{\text{urine}} \times CA_{\text{urine}}/CA_{\text{pool}} \quad (\text{Eqn. 3-1})$$

where:

$V_{\text{pool water ingested}}$	=	volume of pool water ingested (mL)
$V_{\text{urine}}$	=	volume of urine collected over a 24-hour period (mL)
$CA_{\text{urine}}$	=	concentration of cyanuric acid in urine (mg/L)
$CA_{\text{pool}}$	=	concentration of cyanuric acid in pool water (mg/L)

Dufour et al. (2006) estimated pool water intake among 53 swimmers that participated in a pilot study at an outdoor swimming pool treated with chloroisocyanate. This pilot study population included 12 adults (4 males and 8 females) and 41 children between 6 and 15 years of age (20 males and 21 females). The study participants were asked not to swim for 24 hours before or after a 45 minute period of active swimming in the pool. Pool water samples were collected prior to the start of swimming activities and swimmers' urine was collected for 24 hours after the swimming event ended. The pool water and urine sample were analyzed for cyanuric acid.

The results of this pilot study are presented in Table 3-34. The mean volume of water ingested by children over a 45-minute period was 37 mL. The maximum volume of water ingested by children was 154 mL/45 minutes and the 97<sup>th</sup> percentile was 90 mL. Individuals older than 18 years of age ingested an average of 16 mL over a 45-minute period; the maximum amount ingested by these individuals was 53mL over a 45-minute period. The mean ingestion rates for males tended to be higher than that of females, but these differences were not statistically significant. The advantages of this study is that it is one of the first attempts to measure water ingested while swimming. However, the number of study

participants was low and data cannot be broken out by the recommended age categories. As noted by the Dufour et al. (2006), swimming behavior of pool swimmers may be similar to freshwater swimmers, but may differ from salt water swimmers.

Based on the results of the Dufour et al. (2006) study, the recommended mean water ingestion rate for exposure scenarios involving swimming activities is 50 mL/hour for children under 16 years of age (37 mL/0.75 hour, rounded to one significant figure) and the upper percentile value is 100 mL/hour (90 mL/0.75 hour, rounded to one significant figure). For children, ages 18 to <21 years, the recommended mean water ingestion rate for scenarios involving swimming activities is 20 mL/hour (16 mL/0.75 hour, rounded to one significant figure). Because the data set is limited, the upper percentile water ingestion rate for 18 to <21 year olds is based on the maximum value observed in adults in the Dufour et al. (2006) study: 70 mL/hour (53 mL/0.75 hour, rounded to one significant figure).

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Table 3-4. Per Capita<sup>a</sup> Estimates of Combined Direct and Indirect<sup>b</sup> Water Ingestion: Community Water (mL/day)

Age	Sample size	Mean	Percentiles						
			10	25	50	75	90	95	99
Birth to <1 month	91	184	-	-	-	322	687*	839*	860*
1 to <3 months	253	227	-	-	-	456	804	896*	1,165*
3 to <6 months	428	362	-	-	148	695	928	1,056	1,424*
6 to <12 months	714	360	-	17	218	628	885	1,055	1,511*
1 to <2 years	1,040	271	-	60	188	402	624	837	1,215*
2 to <3 years	1,056	317	-	78	246	479	683	877	1,364*
3 to <6 years	4,391	380	4	98	291	547	834	1,078	1,654
6 to <11 years	1,670	447	22	133	350	648	980	1,235	1,870*
11 to <16 years	1,005	606	30	182	459	831	1,387	1,727	2,568*
16 to <18 years	363	731	16	194	490	961	1,562	1,983*	3,720*
18 to <21 years	389	826	24	236	628	1,119	1,770	2,540*	3,889*

<sup>a</sup> Includes all participants whether or not they ingested any water from the source during survey period.  
<sup>b</sup> Direct water defined as water ingested directly as a beverage; indirect water defined as water added in the preparation of food or beverages.  
 - = Zero.  
 \* The sample size does not meet minimum requirements as described in the “Third Report on Nutrition Monitoring in the United States” (LSRO, 1995).

Source: Kahn and Stralka, 2008 and supplementary data.

Table 3-5. Per Capita<sup>a</sup> Estimates of Combined Direct and Indirect<sup>b</sup> Water Ingestion: Bottled Water (mL/day)

Age	Sample size	Mean	Percentiles						
			10	25	50	75	90	95	99
Birth to <1 month	91	104	-	-	-	18	437*	556*	1,007*
1 to <3 months	253	106	-	-	-	-	541	771*	1,056*
3 to <6 months	428	120	-	-	-	-	572	774	1,443*
6 to <12 months	714	120	-	-	-	53	506	761	1,284*
1 to <2 years	1,040	59	-	-	-	-	212	350	801*
2 to <3 years	1,056	76	-	-	-	-	280	494	1,001*
3 to <6 years	4,391	84	-	-	-	-	325	531	1,031*
6 to <11 years	1,670	84	-	-	-	-	330	532	1,079*
11 to <16 years	1,005	111	-	-	-	-	382	709	1,431*
16 to <18 years	363	109	-	-	-	-	426	680*	1,605*
18 to <21 years	389	185	-	-	-	-	514	1,141*	2,364*

<sup>a</sup> Includes all participants whether or not they ingested any water from the source during survey period.  
<sup>b</sup> Direct water defined as water ingested directly as a beverage; indirect water defined as water added in the preparation of food or beverages.  
 - = Zero.  
 \* The sample size does not meet minimum requirements as described in the “Third Report on Nutrition Monitoring in the United States” (LSRO, 1995).

Source: Kahn and Stralka, 2008 and supplementary data.



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Table 3-6. Per Capita<sup>a</sup> Estimates of Combined Direct and Indirect<sup>b</sup> Water Ingestion: Other Sources (mL/day)

Age	Sample size	Mean	Percentiles						
			10	25	50	75	90	95	99
Birth to <1 month	91	13	-	-	-	-	-	-	393*
1 to <3 months	253	35	-	-	-	-	-	367*	687*
3 to <6 months	428	45	-	-	-	-	-	365	938*
6 to <12 months	714	45	-	-	-	-	31	406	963*
1 to <2 years	1,040	22	-	-	-	-	-	118	482*
2 to <3 years	1,056	39	-	-	-	-	52	344	718*
3 to <6 years	4,391	43	-	-	-	-	58	343	830
6 to <11 years	1,670	61	-	-	-	-	181	468	1,047*
11 to <16 years	1,005	102	-	-	-	-	344	786	1,698*
16 to <18 years	363	97	-	-	-	-	295	740*	1,760*
18 to <21 years	389	47	-	-	-	-	-	246*	1,047*

<sup>a</sup> Includes all participants whether or not they ingested any water from the source during survey period.  
<sup>b</sup> Direct water defined as water ingested directly as a beverage; indirect water defined as water added in the preparation of food or beverages.  
 - = Zero.  
 \* The sample size does not meet minimum requirements as described in the “Third Report on Nutrition Monitoring in the United States” (LSRO, 1995).

Source: Kahn and Stralka, 2008 and supplementary data.

Table 3-7. Per Capita<sup>a</sup> Estimates of Combined Direct and Indirect<sup>b</sup> Water Ingestion: All Sources (mL/day)

Age	Sample size	Mean	Percentiles						
			10	25	50	75	90	95	99
Birth to <1 month	91	301	-	-	135	542	846*	877*	1,088*
1 to <3 months	253	368	-	-	267	694	889	1,020*	1,265*
3 to <6 months	428	528	-	89	549	812	1,025	1,303	1,509*
6 to <12 months	714	530	37	181	505	771	1,029	1,278	1,690*
1 to <2 years	1,040	358	68	147	287	477	735	961	1,281*
2 to <3 years	1,056	437	104	211	372	588	825	999	1,662*
3 to <6 years	4,391	514	126	251	438	681	980	1,200	1,794
6 to <11 years	1,670	600	169	304	503	803	1,130	1,409	2,167*
11 to <16 years	1,005	834	224	401	663	1,099	1,649	1,960	3,179*
16 to <18 years	363	964	236	387	742	1,273	1,842	2,344*	3,854*
18 to <21 years	389	1,075	189	406	803	1,394	2,117	2,985*	4,955*

<sup>a</sup> Includes all participants whether or not they ingested any water from the source during survey period.  
<sup>b</sup> Direct water defined as water ingested directly as a beverage; indirect water defined as water added in the preparation of food or beverages.  
 - = Zero.  
 \* The sample size does not meet minimum requirements as described in the “Third Report on Nutrition Monitoring in the United States” (LSRO, 1995).

Source: Kahn and Stralka, 2008 and supplementary data.



Table 3-8. Per Capita<sup>a</sup> Estimates of Combined Direct and Indirect<sup>b</sup> Water Ingestion: All Sources (mL/day)

Age	Sample size	Estimate	Mean		90 <sup>th</sup> percentile		95 <sup>th</sup> percentile		90% B.I.	
			Lower Bound	Upper Bound	Estimate	Lower Bound	Upper Bound	Estimate	Lower Bound	Upper Bound
Birth to <1 month	91	301	215	387	846*	638*	859*	877*	798*	993*
1 to <3 months	253	368	304	432	889	862	896	1,020*	918*	1,070*
3 to <6 months	428	528	485	571	1,025	955	1,083	1,303	1,170	1,351
6 to <12 months	714	530	495	564	1,029	973	1,100	1,278	1,142	1,385
1 to <2 years	1,040	358	338	377	735	686	778	961	879	1,001
2 to <3 years	1,056	437	418	455	825	784	857	999	952	1,051
3 to <6 years	4,391	514	494	533	980	953	1,004	1,200	1,167	1,240
6 to <11 years	1,670	600	571	629	1,130	1,065	1,162	1,409	1,314	1,468
11 to <16 years	1,005	834	770	898	1,649	1,567	1,775	1,960	1,873	2,218
16 to <18 years	363	964	870	1,057	1,842	1,743	1,988	2,344*	2,071*	2,599*
18 to <21 years	389	1,075	980	1,171	2,117	1,952	2,299	2,985*	2,504*	3,785*

<sup>a</sup> Includes all participants whether or not they ingested any water from the source during survey period.  
<sup>b</sup> Direct water defined as water ingested directly as a beverage; indirect water defined as water added in the preparation of food or beverages.  
\* The sample size does not meet minimum requirements as described in the "Third Report on Nutrition Monitoring in the United States" (LSRO, 1995).  
CI = Confidence Interval.  
BI = Bootstrap Interval.

Source: Kahn and Stralka, 2008 and supplementary data.



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Table 3-9. Per Capita<sup>a</sup> Estimates of Combined Direct and Indirect<sup>b</sup> Water Ingestion: Community Water (mL/kg-day)

Age	Sample size	Mean	Percentiles						
			10	25	50	75	90	95	99
Birth to <1 month	88	52	-	-	-	101	196*	232*	253*
1 to <3 months	245	48	-	-	-	91	151	205*	310*
3 to <6 months	411	52	-	-	20	98	135	159	216*
6 to <12 months	678	41	-	2	24	71	102	126	185*
1 to <2 years	1,002	23	-	5	17	34	53	71	106*
2 to <3 years	994	23	-	6	17	33	50	60	113*
3 to <6 years	4,112	22	-	6	17	31	48	61	93
6 to <11 years	1,553	16	1	5	12	22	34	43	71*
11 to <16 years	975	12	1	4	9	16	25	34	54*
16 to <18 years	360	11	-	3	8	15	23	31*	55*
18 to <21 years	383	12	1	4	10	16	17	35*	63*

<sup>a</sup> Includes all participants whether or not they ingested any water from the source during survey period.  
<sup>b</sup> Direct water defined as water ingested directly as a beverage; indirect water defined as water added in the preparation of food or beverages.  
 - = Zero.  
 \* The sample size does not meet minimum requirements as described in the “Third Report on Nutrition Monitoring in the United States” (LSRO, 1995).

Source: Kahn and Stralka, 2008 and supplementary data.

Table 3-10. Per Capita<sup>a</sup> Estimates of Combined Direct and Indirect<sup>b</sup> Water Ingestion: Bottled Water (mL/kg-day)

Age	Sample size	Mean	Percentiles						
			10	25	50	75	90	95	99
Birth to <1 month	88	33	-	-	-	6	131*	243*	324*
1 to <3 months	245	22	-	-	-	-	97	161*	242*
3 to <6 months	411	16	-	-	-	-	74	117	193*
6 to <12 months	678	13	-	-	-	4	52	87	139*
1 to <2 years	1,002	5	-	-	-	-	18	28	67*
2 to <3 years	994	5	-	-	-	-	19	35	84*
3 to <6 years	4,112	5	-	-	-	-	18	30	59
6 to <11 years	1,553	3	-	-	-	-	10	18	41*
11 to <16 years	975	2	-	-	-	-	8	14	26*
16 to <18 years	360	2	-	-	-	-	6	10*	27*
18 to <21 years	383	3	-	-	-	-	8	19*	34*

<sup>a</sup> Includes all participants whether or not they ingested any water from the source during survey period.  
<sup>b</sup> Direct water defined as water ingested directly as a beverage; indirect water defined as water added in the preparation of food or beverages.  
 - = Zero.  
 \* The sample size does not meet minimum requirements as described in the “Third Report on Nutrition Monitoring in the United States” (LSRO, 1995).

Source: Kahn and Stralka, 2008 and supplementary data.



Table 3-11. Per Capita<sup>a</sup> Estimates of Combined Direct and Indirect<sup>b</sup> Water Ingestion: Other Sources (mL/kg-day)

Age	Sample size	Mean	Percentiles						
			10	25	50	75	90	95	99
Birth to <1 month	88	4	-	-	-	-	-	-	122*
1 to <3 months	245	7	-	-	-	-	-	52*	148*
3 to <6 months	411	7	-	-	-	-	-	55	155*
6 to <12 months	678	5	-	-	-	-	3	35	95*
1 to <2 years	1,002	2	-	-	-	-	-	11	45*
2 to <3 years	994	3	-	-	-	-	4	23	61*
3 to <6 years	4,112	2	-	-	-	-	3	19	48
6 to <11 years	1,553	2	-	-	-	-	7	16	36*
11 to <16 years	975	2	-	-	-	-	7	14	34*
16 to <18 years	360	2	-	-	-	-	5	11*	27*
18 to <21 years	383	1	-	-	-	-	-	4*	14*

<sup>a</sup> Includes all participants whether or not they ingested any water from the source during survey period.  
<sup>b</sup> Direct water defined as water ingested directly as a beverage; indirect water defined as water added in the preparation of food or beverages.  
 - = Zero.  
 \* The sample size does not meet minimum requirements as described in the “Third Report on Nutrition Monitoring in the United States” (LSRO, 1995).

Source: Kahn and Stralka, 2008 and supplementary data.

Table 3-12. Per Capita<sup>a</sup> Estimates of Combined Direct and Indirect<sup>b</sup> Water Ingestion: All Sources (mL/kg-day)

Age	Sample size	Mean	Percentiles						
			10	25	50	75	90	95	99
Birth to <1 month	88	89	-	-	21	168	235*	269*	338*
1 to <3 months	245	77	-	-	46	134	173	246*	336*
3 to <6 months	411	75	-	9	73	118	156	186	225*
6 to <12 months	678	59	4	20	53	86	118	148	194*
1 to <2 years	1,002	31	6	13	24	39	63	85	122*
2 to <3 years	994	31	7	15	26	41	59	73	130*
3 to <6 years	4,112	29	7	14	25	38	56	69	102
6 to <11 years	1,553	21	6	10	18	27	39	50	76*
11 to <16 years	975	16	4	8	13	20	31	39	60*
16 to <18 years	360	15	4	6	12	18	28	37*	59*
18 to <21 years	383	16	3	6	12	21	32	41*	73*

<sup>a</sup> Includes all participants whether or not they ingested any water from the source during survey period.  
<sup>b</sup> Direct water defined as water ingested directly as a beverage; indirect water defined as water added in the preparation of food or beverages.  
 - = Zero.  
 \* The sample size does not meet minimum requirements as described in the “Third Report on Nutrition Monitoring in the United States” (LSRO, 1995).

Source: Kahn and Stralka, 2008 and supplementary data.



Table 3-13. Per Capita<sup>a</sup> Estimates of Total Direct and Indirect<sup>b</sup> Water Ingestion: All Sources (mL/kg-day)

Age	Sample size	Mean									
		Estimate		90% C.I.		90 <sup>th</sup> percentile			95 <sup>th</sup> percentile		
		Lower Bound	Upper Bound	Lower Bound	Upper Bound	Estimate	Lower Bound	Upper Bound	Estimate	Lower Bound	Upper Bound
Birth to <1 month	88	89	64	114	235*	198*	269*	269*	236*	332*	
1 to <3 months	245	77	62	91	173	164	217	246*	187*	295*	
3 to <6 months	411	75	68	82	156	145	162	186	176	199	
6 to <12 months	678	59	54	63	118	112	128	148	134	166	
1 to <2 years	1,002	31	29	32	63	59	68	85	73	95	
2 to <3 years	994	31	30	33	59	57	62	73	69	81	
3 to <6 years	4,112	29	28	30	56	54	56	69	66	72	
6 to <11 years	1,553	21	20	22	39	36	41	50	47	52	
11 to <16 years	975	16	15	17	31	29	34	39	36	41	
16 to <18 years	360	15	13	16	28	27	32	37*	33*	44*	
18 to <21 years	383	16	14	17	32	29	35	41*	36*	44*	

<sup>a</sup> Includes all participants whether or not they ingested any water from the source during survey period.  
<sup>b</sup> Direct water defined as water ingested directly as a beverage; indirect water defined as water added in the preparation of food or beverages.  
 \* The sample size does not meet minimum requirements as described in the "Third Report on Nutrition Monitoring in the United States" (LSRO, 1995).  
 CI = Confidence Interval.  
 BI = Bootstrap Interval.

Source: Kahn and Stralka, 2008 and supplementary data.



Table 3-14. Consumers Only<sup>a</sup> Estimates of Combined Direct and Indirect<sup>b</sup> Water Ingestion: Community Water (mL/day)

Age	Sample size	Mean	Percentiles						
			10	25	50	75	90	95	99
Birth to <1 month	40	470*	32*	215*	482*	692*	849*	858*	919*
1 to <3 months	114	552	67*	339	533	801	943*	1,053*	1,264*
3 to <6 months	281	556	44	180	561	837	1,021	1,171*	1,440*
6 to <12 months	562	467	44	105	426	710	971	1,147	1,586*
1 to <2 years	916	308	43	107	229	428	674	893	1,248*
2 to <3 years	934	356	49	126	281	510	700	912	1,388*
3 to <6 years	3,960	417	57	146	336	581	867	1,099	1,684
6 to <11 years	1,555	480	74	177	373	682	994	1,251	2,024*
11 to <16 years	937	652	106	236	487	873	1,432	1,744	2,589*
16 to <18 years	341	792	106	266	591	987	1,647	2,002*	3,804*
18 to <21 years	364	895	114	295	674	1,174	1,860	2,565*	3,917*

<sup>a</sup> Excludes individuals who did not ingest water from the source during the survey period.  
<sup>b</sup> Direct water defined as water ingested directly as a beverage; indirect water defined as water added in the preparation of food or beverages.  
\* The sample size does not meet minimum requirements as described in the “Third Report on Nutrition Monitoring in the United States” (LSRO, 1995).

Source: Kahn and Stralka, 2008 and supplementary data.

Table 3-15. Consumers Only<sup>a</sup> Estimates of Combined Direct and Indirect<sup>b</sup> Water Ingestion: Bottled Water (mL/day)

Age	Sample size	Mean	Percentiles						
			10	25	50	75	90	95	99
Birth to <1 month	25	-	-	-	-	-	-	-	-
1 to <3 months	64	450*	31*	62*	329*	743*	886*	1,045*	1,562*
3 to <6 months	103	507	48*	88	493	747	1,041*	1,436*	1,506*
6 to <12 months	200	425	47	114	353	630	945*	1,103*	1,413*
1 to <2 years	229	262	45	88	188	324	600	709*	1,083*
2 to <3 years	232	352	57	116	241	471	736	977*	1,665*
3 to <6 years	1,021	380	72	149	291	502	796	958	1,635*
6 to <11 years	332	430	88	168	350	557	850	1,081*	1,823*
11 to <16 years	192	570	116*	229	414	719	1,162*	1,447*	2,705*
16 to <18 years	63	615*	85*	198*	446*	779*	1,365*	1,613*	2,639*
18 to <21 years	97	769	118*	236	439	943	1,788*	2,343*	3,957*

<sup>a</sup> Excludes individuals who did not ingest water from the source during the survey period.  
<sup>b</sup> Direct water defined as water ingested directly as a beverage; indirect water defined as water added in the preparation of food or beverages.  
- Insufficient sample size to estimate mean and percentiles.  
\* The sample size does not meet minimum requirements as described in the “Third Report on Nutrition Monitoring in the United States” (LSRO, 1995).

Source: Kahn and Stralka, 2008 and supplementary data.





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Table 3-16. Consumers Only<sup>a</sup> Estimates of Combined Direct and Indirect<sup>b</sup> Water Ingestion: Other Sources (mL/day)

Age	Sample size	Mean	Percentiles						
			10	25	50	75	90	95	99
Birth to <1 month	3	-	-	-	-	-	-	-	-
1 to <3 months	19	-	-	-	-	-	-	-	-
3 to <6 months	38	562*	59*	179*	412*	739*	983*	1,205*	2,264*
6 to <12 months	73	407*	31*	121*	300*	563*	961*	1,032*	1,144*
1 to <2 years	98	262	18*	65	143	371	602*	899*	1,204*
2 to <3 years	129	354	56*	134	318	472	704*	851*	1,334*
3 to <6 years	533	396	59	148	314	546	796	1,019	1,543*
6 to <11 years	219	448	89	177	347	682	931	1,090*	1,596*
11 to <16 years	151	687	171*	296	482	947	1,356*	1,839*	2,891*
16 to <18 years	53	657*	152*	231*	398*	823*	1,628*	1,887*	2,635*
18 to <21 years	33	569*	103*	142*	371*	806*	1,160*	1,959*	1,962*

<sup>a</sup> Excludes individuals who did not ingest water from the source during the survey period.  
<sup>b</sup> Direct water defined as water ingested directly as a beverage; indirect water defined as water added in the preparation of food or beverages.  
- Insufficient sample size to estimate means and percentiles.  
\* The sample size does not meet minimum requirements as described in the “Third Report on Nutrition Monitoring in the United States” (LSRO, 1995).

Source: Kahn and Stralka, 2008 and supplementary data.

Table 3-17. Consumers Only<sup>a</sup> Estimates of Combined Direct and Indirect<sup>b</sup> Water Ingestion: All Sources (mL/day)

Age	Sample size	Mean	Percentiles						
			10	25	50	75	90	95	99
Birth to <1 month	58	511*	51*	266*	520*	713*	858*	986*	1,274*
1 to <3 months	178	555	68*	275	545	801	946*	1,072*	1,470*
3 to <6 months	363	629	69	384	612	851	1,064	1,330*	1,522*
6 to <12 months	667	567	90	250	551	784	1,050	1,303	1,692*
1 to <2 years	1,017	366	84	159	294	481	735	978	1,281*
2 to <3 years	1,051	439	105	213	375	589	825	1,001	1,663*
3 to <6 years	4,350	518	134	255	442	682	980	1,206	1,796
6 to <11 years	1,659	603	177	310	506	805	1,131	1,409	2,168*
11 to <16 years	1,000	837	229	404	665	1,105	1,649	1,961	3,184*
16 to <18 years	357	983	252	395	754	1,276	1,865	2,346*	3,866*
18 to <21 years	383	1,094	219	424	823	1,397	2,144	3,002*	4,967*

<sup>a</sup> Excludes individuals who did not ingest water from the source during the survey period.  
<sup>b</sup> Direct water defined as water ingested directly as a beverage; indirect water defined as water added in the preparation of food or beverages.  
\* The sample size does not meet minimum requirements as described in the “Third Report on Nutrition Monitoring in the United States” (LSRO, 1995).

Source: Kahn and Stralka, 2008 and supplementary data.



Table 3-18. Consumers Only<sup>a</sup> Estimates of Combined Direct and Indirect<sup>b</sup> Water Ingestion: All Sources (mL/day)

Age	Sample size	Mean						90 <sup>th</sup> percentile					
		90% C.I.			90% B.I.			90% B.I.			95 <sup>th</sup> percentile		
		Estimate	Lower	Upper	Estimate	Lower	Upper	Estimate	Lower	Upper	Estimate	Lower	Upper
Birth to <1 month	58	511*	417*	606*	858*	856*	993*	986*	974*	1,076*			
1 to <3 months	178	555	487	622	946*	891*	1,042*	1,072*	1,022*	1,183*			
3 to <6 months	363	629	587	672	1,064	1,011	1,177	1,330*	1,183*	1,431*			
6 to <12 months	667	567	534	600	1,050	1,001	1,141	1,303	1,181	1,372			
1 to <2 years	1,017	366	346	385	735	715	765	978	915	1,001			
2 to <3 years	1,051	439	420	457	825	784	857	1,001	944	1,075			
3 to <6 years	4,350	518	499	537	980	961	1,000	1,206	1,171	1,253			
6 to <11 years	1,659	603	574	632	1,131	1,075	1,162	1,409	1,336	1,468			
11 to <16 years	1,000	837	773	901	1,649	1,568	1,749	1,961	1,873	2,104			
16 to <18 years	357	983	896	1,071	1,865	1,774	1,982	2,346*	2,129*	2,599*			
18 to <21 years	383	1,094	999	1,189	2,144	1,951	2,299	3,002*	2,576*	3,785*			

<sup>a</sup> Excludes individuals who did not ingest water from the source during the survey period.  
<sup>b</sup> Direct water defined as water ingested directly as a beverage; indirect water defined as water added in the preparation of food or beverages.  
\* The sample size does not meet minimum requirements as described in the "Third Report on Nutrition Monitoring in the United States" (LSRO, 1995).  
CI = Confidence Interval.  
BI = Bootstrap Interval.  
Source: Kahn and Stralka, 2008.



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Table 3-19. Consumers Only<sup>a</sup> Estimates of Direct and Indirect<sup>b</sup> Water Ingestion: Community Water (mL/kg-day)

Age	Sample size	Mean	Percentiles						
			10	25	50	75	90	95	99
Birth to <1 month	37	137*	11*	65*	138*	197*	235*	238*	263*
1 to <3 months	108	119	12*	71	107	151	228*	285*	345*
3 to <6 months	269	80	7	27	77	118	148	173*	222*
6 to <12 months	534	53	5	12	47	81	112	129	186*
1 to <2 years	880	27	4	9	20	36	56	75	109*
2 to <3 years	879	26	4	9	21	36	52	62	121*
3 to <6 years	3,703	24	3	8	19	33	49	65	97
6 to <11 years	1,439	17	3	6	13	23	35	45	72*
11 to <16 years	911	13	2	5	10	17	26	34	54*
16 to <18 years	339	12	1	4	9	16	24	32*	58*
18 to <21 years	361	13	2	5	10	17	29	35*	63*

<sup>a</sup> Excludes individuals who did not ingest water from the source during the survey period.  
<sup>b</sup> Direct water defined as water ingested directly as a beverage; indirect water defined as water added in the preparation of food or beverages.  
\* The sample size does not meet minimum requirements as described in the “Third Report on Nutrition Monitoring in the United States” (LSRO, 1995).

Source Kahn and Stralka, 2008 and supplementary data.

Table 3-20. Consumers Only<sup>a</sup> Estimates of Direct and Indirect<sup>b</sup> Water Ingestion: Bottled Water (mL/kg-day)

Age	Sample size	Mean	Percentiles						
			10	25	50	75	90	95	99
Birth to <1 month	25	-	-	-	-	-	-	-	-
1 to <3 months	64	92*	7*	12*	76*	151*	164*	220*	411*
3 to <6 months	95	72	6*	15	69	100	149*	184*	213*
6 to <12 months	185	47	5*	11	34	73	104*	120*	166*
1 to <2 years	216	22	5	8	16	27	49	66*	103*
2 to <3 years	211	25	4	8	17	35	54	81*	91*
3 to <6 years	946	21	4	8	16	29	45	57	90*
6 to <11 years	295	15	3	5	11	19	30	42*	69*
11 to <16 years	180	11	2*	4	8	14	24*	27*	44*
16 to <18 years	63	10*	1*	3*	7*	11*	23*	27*	37*
18 to <21 years	93	11	2*	3	6	14	27*	30*	54*

<sup>a</sup> Excludes individuals who did not ingest water from the source during the survey period.  
<sup>b</sup> Direct water defined as water ingested directly as a beverage; indirect water defined as water added in the preparation of food or beverages.  
- Insufficient sample size to estimate means and percentiles.  
\* The sample size does not meet minimum requirements as described in the “Third Report on Nutrition Monitoring in the United States” (LSRO, 1995).

Source: Kahn and Stralka, 2008 and supplementary data.



Table 3-21. Consumers Only<sup>a</sup> Estimates of Direct and Indirect<sup>b</sup> Water Ingestion: Other Sources (mL/kg-day)

Age	Sample size	Mean	Percentiles						
			10	25	50	75	90	95	99
Birth to <1 month	3	-	-	-	-	-	-	-	-
1 to <3 months	19	-	-	-	-	-	-	-	-
3 to <6 months	38	80*	10*	23*	59*	106*	170*	200*	246*
6 to <12 months	68	44*	4*	10*	33*	65*	95*	106*	147*
1 to <2 years	95	23	1*	5	13	28	46*	84*	125*
2 to <3 years	124	26	4*	10	21	34	55*	66*	114*
3 to <6 years	505	22	3	8	17	30	46	56	79*
6 to <11 years	208	16	3	6	12	23	32	39*	62*
11 to <16 years	148	13	3*	6	9	18	27*	36*	56*
16 to <18 years	52	10*	2*	4*	7*	12*	24*	29*	43*
18 to <21 years	33	8*	1*	2*	6*	10*	16*	27*	31*

<sup>a</sup> Excludes individuals who did not ingest water from the source during the survey period.  
<sup>b</sup> Direct water defined as water ingested directly as a beverage; indirect water defined as water added in the preparation of food or beverages.  
- Means insufficient sample size to estimate distribution percentiles.  
\* The sample size does not meet minimum requirements as described in the “Third Report on Nutrition Monitoring in the United States” (LSRO, 1995).

Source Kahn and Stralka, 2008 and supplementary data.

Table 3-22. Consumers Only<sup>a</sup> Estimates of Direct and Indirect<sup>b</sup> Water Ingestion: All Sources (mL/kg-day)

Age	Sample size	Mean	Percentiles						
			10	25	50	75	90	95	99
Birth to <1 month	55	153*	13*	83*	142*	208*	269*	273*	400*
1 to <3 months	172	116	12*	50	107	161	216*	291*	361*
3 to <6 months	346	90	9	52	86	125	161	195*	233*
6 to <12 months	631	63	10	27	58	88	120	152	198*
1 to <2 years	980	31	7	14	25	40	64	86	122*
2 to <3 years	989	31	7	15	27	41	59	73	130*
3 to <6 years	4,072	29	7	15	25	38	56	70	102*
6 to <11 years	1,542	21	6	10	18	27	39	50	76*
11 to <16 years	970	16	4	8	13	20	31	39	60*
16 to <18 years	354	15	4	7	12	18	29	37*	60*
18 to <21 years	378	16	3	6	12	21	32	41*	73*

<sup>a</sup> Excludes individuals who did not ingest water from the source during the survey period.  
<sup>b</sup> Direct water defined as water ingested directly as a beverage; indirect water defined as water added in the preparation of food or beverages.  
\* The sample size does not meet minimum requirements as described in the “Third Report on Nutrition Monitoring in the United States” (LSRO, 1995).

Source Kahn and Stralka, 2008 and supplementary data.



Table 3-23. Consumer Only<sup>a</sup> Estimates of Total Direct and Indirect<sup>b</sup> Water Ingestion (mL/kg-day)

Age	Sample size	Mean						90 <sup>th</sup> percentile						95 <sup>th</sup> percentile					
		Estimate		90% C.I.		90% B.I.		Estimate		90% B.I.		Estimate		90% B.I.		Estimate		90% B.I.	
		Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound
Birth to <1 month	55	153*	125*	181*	269*	234*	273*	273*	263*	273*	273*	273*	273*	263*	273*	273*	263*	273*	332*
1 to <3 months	172	116	100	132	216*	176*	259*	259*	214*	259*	259*	259*	259*	214*	259*	259*	214*	259*	316*
3 to <6 months	346	90	83	97	161	145	178	178	174*	178	178	178	178	174*	178	178	174*	178	212*
6 to <12 months	631	63	59	67	120	117	127	127	137	127	127	127	127	137	127	127	137	127	166
1 to <2 years	980	31	30	33	64	57	67	67	70	67	67	67	67	70	67	67	70	67	89
2 to <3 years	989	31	30	33	59	56	61	61	67	61	61	61	61	67	61	61	67	61	81
3 to <6 years	4,072	29	28	30	56	54	57	57	67	54	57	57	57	67	57	57	67	57	73
6 to <11 years	1,542	21	20	22	39	37	41	41	46	37	41	41	41	46	41	41	46	41	52
11 to <16 years	970	16	15	17	31	29	33	33	38	29	33	33	33	38	33	33	38	33	42
16 to <18 years	354	15	14	16	29	27	32	32	33v	27	32	32	32	33v	32	32	33v	32	44*
18 to <21 years	378	16	15	18	32	29	35	35	36*	29	35	35	35	36*	35	35	36*	35	56*

<sup>a</sup> Excludes individuals who did not ingest water from the source during the survey period.  
<sup>b</sup> Direct water defined as water ingested directly as a beverage; indirect water defined as water added in the preparation of food or beverages.  
 \* The sample size does not meet minimum requirements as described in the "Third Report on Nutrition Monitoring in the United States".  
 CI = Confidence Interval.  
 BI = Bootstrap Interval.

Source: Kahn and Stralka, 2008 and supplementary data.



Table 3-24. Water Ingested (mL/day)<sup>a</sup> from Water By Itself and Water Added to Other Beverages and Foods

Category	6 Weeks (N = 124)	3 Months (N = 120)	6 Months (N = 99)	9 Months (N = 77)
Water by Itself	Range	0-355	0-355	0-473
	Per capita mean <sup>b</sup> ± SD	30 ± 89	30 ± 59	89 ± 89
	Consumer only mean <sup>c</sup> Percent consuming <sup>d</sup>	89 28	89 24	118 42
Water Added to Formula Powdered Concentrate	Range	0-1,242	0-1,242	0-1,064
	Per capita mean ± SD	177 ± 296	266 ± 384	207 ± 325
	Consumer only mean Percent consuming	473 39	621 42	562 48
Liquid Concentrate	Range	0-621	0-680	0-532
	Per capita mean ± SD	89 ± 148	237 ± 207	59 ± 148
	Consumer only mean Percent consuming	355 23	384 30	325 21
All Concentrated Formula	Range	0-1,242	0-1,242	0-1,064
	Per capita mean ± SD	266 ± 296	384 ± 355	266 ± 296
	Consumer only mean Percent consuming	444 60	562 68	503 56
Water Added to Juices and Other Beverages	Range	0-118	0-710	0-887
	Per capita mean ± SD	<30 ± 30	30 ± 89	59 ± 148
	Consumer only mean Percent consuming	89 3	207 9	207 32
Water Added to Powdered Baby Foods and Cereals	Range	0-30	0-177	0-177
	Per capita mean ± SD	<30 ± 30	<30 ± 30	30 ± 59
	Consumer only mean Percent consuming	30 2	59 17	89 43
Water Added to Other Foods (Soups, Jell-o, Puddings)	Range	-	0-118	0-355
	Per capita mean ± SD	-	30 ± 30	30 ± 59
	Consumer only mean Percent consuming	- 0	89 2	118 29
ALL SOURCES OF WATER	Range	0-1,242	0-1,419	0-1,745
	Per capita mean ± SD	296 ± 325	414 ± 414	444 ± 355
	Consumer only mean Percent consuming	414 68	562 77	473 94

<sup>a</sup> Converted from ounces/day; 1 fluid ounce = 29.57 mL.

<sup>b</sup> Mean intake among entire sample.

<sup>c</sup> Mean intake for only those ingesting water from the particular category.

<sup>d</sup> Percentage of infants receiving water from that individual source.

N = Number of observations.

SD = Standard Deviation.

Source: Levy et al., 1995.



Table 3-25. Mean Water Consumption (mL/kg-day) by Race/Ethnicity

Race/Ethnic Group	N	Plain Tap Water	Milk and Milk Drinks	Reconstituted Formula	RTF Formula	Baby Food	Juices and Carbonated Drinks	Non-carbonated Drinks	Other	Total <sup>a</sup>
Black non-Hispanic	121	21 (1.7)	24 (4.6)	35 (6.0)	4 (2.0)	8 (1.6)	2 (0.7)	14 (1.3)	21 (1.7)	129 (5.7)
White non-Hispanic	620	13 (0.8)	23 (1.2)	29 (2.7)	8 (1.5)	10 (1.2)	1 (0.2)	11 (0.7)	18 (0.8)	113 (2.6)
Hispanic	146	15 (1.2)	23 (2.4)	38 (7.3)	12 (4.0)	10 (1.4)	1 (0.3)	10 (1.6)	16 (1.4)	123 (5.2)
Other	59	21 (2.4)	19 (3.7)	31 (9.1)	19 (11.2)	7 (4.0)	1 (0.5)	8 (2.0)	19 (3.2)	124 (10.6)

<sup>a</sup> Totals may be slightly different from the sums of all categories due to rounding.  
 N = Number of observations.  
 RTF = Ready-to-Feed.  
 Note: Standard Error shown in parentheses.  
 Source: Heller et al., 2000.



Table 3-26. Plain Tap Water and Total Water Consumption by Age, Sex, Region, Urbanicity, and Poverty Category					
Variable	N	Plain Tap Water (mL/kg-day)		Total Water (mL/kg-day)	
		Mean	SE	Mean	SE
Age					
<12 months	296	11	1.0	130	4.6
12-24 months	650	18	0.8	108	1.7
Sex					
Male	475	15	1.0	116	4.1
Female	471	15	0.8	119	3.2
Region					
Northeast	175	13	1.4	121	6.3
Midwest	197	14	1.0	120	3.1
South	352	15	1.3	113	3.7
West	222	17	1.1	119	4.6
Urbanicity					
Urban	305	16	1.5	123	3.5
Suburban	446	13	0.9	117	3.1
Rural	195	15	1.2	109	3.9
Poverty category <sup>a</sup>					
0-1.30	289	19	1.5	128	2.6
1.31-3.50	424	14	1.0	117	4.2
>3.50	233	12	1.3	109	3.5
Total	946	15	0.6	118	2.3
<sup>a</sup> Poverty category represents family's annual incomes of 0-1.30, 1.31-3.50, and greater than 3.50 times the federal poverty level. N = Number of observations. SE = Standard Error.  Source: Heller et al., 2000.					





Table 3-27. Intake of Water from Various Sources in 2-13-y-old Participants of the DONALD Study 1985-1999				
Water Intake from:	Boys and girls 2-3 years N = 858 <sup>b</sup>	Boys and girls 4-8 years N = 1,795 <sup>b</sup>	Boys 9-13 years N = 541 <sup>b</sup>	Girls 9-13 years N = 542 <sup>b</sup>
Mean				
Water in Food (mL/day) <sup>a</sup>	365 (33) <sup>c</sup>	487 (36)	673 (36)	634 (38)
Beverages (mL/day) <sup>a</sup>	614 (55)	693 (51)	969 (51)	823 (49)
Milk (mL/day) <sup>a</sup>	191 (17)	177 (13)	203 (11)	144 (9)
Mineral water (mL/day) <sup>a</sup>	130 (12)	179 (13)	282 (15)	242 (15)
Tap water (mL/day) <sup>a</sup>	45 (4)	36 (3)	62 (3)	56 (3)
Juice (mL/day) <sup>a</sup>	114 (10)	122 (0)	133 (7)	138 (8)
Soft drinks (mL/day) <sup>a</sup>	57 (5)	111 (8)	203 (11)	155 (9)
Coffee/tea (mL/day) <sup>a</sup>	77 (7)	69 (5)	87 (4)	87 (5)
Mean ± SD				
Total water intake <sup>a,d</sup> (mL/day)	1,114 ± 289	1,363 ± 333	1,891 ± 428	1,676 ± 386
Total water intake <sup>a,d</sup> (mL/kg-day)	78 ± 22	61 ± 13	49 ± 11	43 ± 10
Total water intake <sup>a,d</sup> (mL/kcal-day)	1.1 ± 0.3	0.9 ± 0.2	1.0 ± 0.2	1.0 ± 0.2
<sup>a</sup> Converted from g/day, g/kg-day, or g/kcal-day; 1 g = 1 mL. <sup>b</sup> N = Number of records. <sup>c</sup> Percent of total water shown in parentheses. <sup>d</sup> Total water = water in food + beverages + oxidation. SD = Standard deviation.				
Source: Sichert-Hellert et al., 2001.				



Table 3-28. Mean ( $\pm$  Standard Error) Fluid Intake (mL/kg/day) by Children Aged 1-10 years, NHANES III, 1988-94

	Total Sample (N = 7,925)	Sample with Temperature Information (N = 3,869)	Sample without Temperature Information (N = 4,056)
Total fluid	84 $\pm$ 1.0	84 $\pm$ 1.0	85 $\pm$ 1.4
Plain water	27 $\pm$ 0.8	27 $\pm$ 1.0	26 $\pm$ 1.1
Milk	18 $\pm$ 0.3	18 $\pm$ 0.6	18 $\pm$ 0.4
Carbonated drinks	6 $\pm$ 0.2	5 $\pm$ 0.3	6 $\pm$ 0.3
Juice	12 $\pm$ 0.3	11 $\pm$ 0.6	12 $\pm$ 0.4

N = Number of observations.

Source: Sohn et al., 2001.



Table 3-29. Estimated Mean ( $\pm$  Standard Error) Amount of Total Fluid and Plain Water Intake among Children<sup>a</sup> Aged 1-10 Years: (NHANES III, 1988-94)

	N	Total Fluid		Plain Water	
		mL/day	mL/kg-day	mL/day	mL/kg-day
<b>Age (years)</b>					
1	578	1,393 $\pm$ 31	124 $\pm$ 2.9	298 $\pm$ 19	26 $\pm$ 1.8
2	579	1,446 $\pm$ 31	107 $\pm$ 2.3	430 $\pm$ 26	32 $\pm$ 1.9
3	502	1,548 $\pm$ 75	100 $\pm$ 4.6	482 $\pm$ 27	31 $\pm$ 1.8
4	511	1,601 $\pm$ 41	91 $\pm$ 2.8	517 $\pm$ 23	29 $\pm$ 1.3
5	465	1,670 $\pm$ 54	84 $\pm$ 2.3	525 $\pm$ 36	26 $\pm$ 1.7
6	255	1,855 $\pm$ 125	81 $\pm$ 4.9	718 $\pm$ 118	31 $\pm$ 4.7
7	235	1,808 $\pm$ 66	71 $\pm$ 2.3	674 $\pm$ 46	26 $\pm$ 1.9
8	247	1,792 $\pm$ 37	61 $\pm$ 1.8	626 $\pm$ 37	21 $\pm$ 1.2
9	254	2,113 $\pm$ 78	65 $\pm$ 2.1	878 $\pm$ 59	26 $\pm$ 1.4
10	243	2,051 $\pm$ 97	58 $\pm$ 2.4	867 $\pm$ 74	24 $\pm$ 2.0
<b>Sex</b>					
Male	1,974	1,802 $\pm$ 30	86 $\pm$ 1.8	636 $\pm$ 32	29 $\pm$ 1.3
Female	1,895	1,664 $\pm$ 24	81 $\pm$ 1.5	579 $\pm$ 26	26 $\pm$ 1.0
<b>Race/ethnicity</b>					
White	736	1,653 $\pm$ 26	79 $\pm$ 1.8	552 $\pm$ 34	24 $\pm$ 1.3
African American	1,122	1,859 $\pm$ 42	88 $\pm$ 1.8	795 $\pm$ 36	36 $\pm$ 1.5
Mexican American	1,728	1,817 $\pm$ 25	89 $\pm$ 1.7	633 $\pm$ 23	29 $\pm$ 1.1
Other	283	1,813 $\pm$ 47	90 $\pm$ 4.2	565 $\pm$ 39	26 $\pm$ 1.7
<b>Poverty income ratio<sup>b</sup></b>					
Low	1,868	1,828 $\pm$ 32	93 $\pm$ 2.6	662 $\pm$ 27	32 $\pm$ 1.3
Medium	1,204	1,690 $\pm$ 31	80 $\pm$ 1.6	604 $\pm$ 35	26 $\pm$ 1.4
High	379	1,668 $\pm$ 54	76 $\pm$ 2.5	533 $\pm$ 41	22 $\pm$ 1.7
<b>Region<sup>c,d</sup></b>					
Northeast	679	1,735 $\pm$ 31	87 $\pm$ 2.3	568 $\pm$ 52	26 $\pm$ 2.1
Midwest	699	1,734 $\pm$ 45	84 $\pm$ 1.5	640 $\pm$ 54	29 $\pm$ 1.8
South	869	1,739 $\pm$ 31	83 $\pm$ 2.2	613 $\pm$ 24	28 $\pm$ 1.3
West	1,622	737 $\pm$ 25	81 $\pm$ 1.7	624 $\pm$ 44	27 $\pm$ 1.9
<b>Urban/rural<sup>d</sup></b>					
Urban	3,358	1,736 $\pm$ 18	84 $\pm$ 1.0	609 $\pm$ 29	27 $\pm$ 1.1
Rural	511	1,737 $\pm$ 19	84 $\pm$ 4.3	608 $\pm$ 20	28 $\pm$ 1.2
<b>Total</b>	<b>3,869</b>	<b>1,737 <math>\pm</math> 15</b>	<b>84 <math>\pm</math> 1.1</b>	<b>609 <math>\pm</math> 24</b>	<b>27 <math>\pm</math> 1.0</b>
<sup>a</sup>	Children for whom temperature data were obtained.				
<sup>b</sup>	Based on ratio of household income to federal poverty threshold. Low: $\leq$ 1.300; medium: 1.301-3.500; high $\geq$ 3.501.				
<sup>c</sup>	All variables except for Region and Urban/rural showed statistically significant differences for both total fluid and plain water intake by Bonferroni multiple comparison method.				
<sup>d</sup>	Northeast = Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont; Midwest = Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, Wisconsin; South = Alabama, Arkansas, Delaware, District of Columbia, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, West Virginia; West = Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, Wyoming.				
N	= Number of observations.				
Source:	Sohn et al., 2001.				



Table 3-30. Tap Water Intake in Breastfed and Formula-fed Infants and Mixed-fed Young Children at Different Age Points

Age	N <sup>a</sup>	Tap water intake <sup>b</sup> (mL/day)					Tap water intake <sup>b</sup> (mL/kg-day)											
		Mean	SD	Median	P95	Max	Mean	SD	Mean	SD	Mean	SD	% <sup>c</sup>	% <sup>f</sup>				
<b>Breastfed</b>																		
≤1 year, total	30	130	180	50	525	1,172	17	24**	6	65	150	17	15	23**	85	2.4	4.7**	15
3 months	11	67	167	0	493	746	10	25**	0	74	125	10	10	25**	97	0.3	1.9**	3
6 months	12	136	150	68	479	634	18	20**	8	5*8	85	18	14	19**	79	3.8	6.3*	21
9 months	47	254	218	207	656	1,172	30	27**	23	77	150	28	26	27**	87	3.7	3.4	13
12 months	18	144	170	85	649	649	15	18**	9	66	66	19	13	18**	86	2.2	2.1	14
<b>Formula fed</b>																		
≤1 year, total	75	441	244	440	828	1,603	53	33	49	115	200	51	49	33	92	4.0	8.0	8
3 months	78	662	154	673	874	994	107	23	107	147	159	93	103	28	97	3.4	17.9	3
6 months	14	500	178	519	757	888	63	23	65	99	109	64	59	25	92	4.8	8.0	8
9 months	24	434	236	406	839	1,579	49	27	45	94	200	50	44	27	91	4.5	6.3	9
12 months	29	360	256	335	789	1,603	37	26	32	83	175	39	33	25	91	3.3	3.7	9
<b>Mixed - Breast and Formula</b>																		
1-3 years, total	90	241	243	175	676	2,441	19	20	14	56	203	24	15	20	78	3.9	5.5	22
18 months	27	280	264	205	828	1,881	25	23	18	70	183	28	22	23	88	3.0	4.1	12
24 months	29	232	263	158	630	2,441	18	21	12	49	203	23	15	21	80	3.7	5.0	20
36 months	33	217	199	164	578	1,544	14	13	11	36	103	22	9	12	66	4.9	6.6	34

<sup>a</sup> Numbers of 3-day diet records.  
<sup>b</sup> Total tap water = tap water from the household and tap water from food manufacturing. Converted from g/day and g/kg-day; 1 g = 1 mL.  
<sup>c</sup> Tap water from household = tap water from the household tap consumed directly as a beverage or used to prepare foods and beverages.  
<sup>d</sup> Tap water from food = manufacturing tap water from the industrial food production used for the preparation of foods (bread, butter/margarine, tinned fruit, vegetables and legumes, ready to serve meals, commercial weaning food) and mixed beverages (lemonade, soft drinks).  
<sup>e</sup> Mean as a percentage of total water.  
<sup>f</sup> Mean as a percentage of total tap water.  
\* Significantly different from formula-fed infants, p<0.05.  
\*\* Significantly different from formula-fed infants, p<0.0001.  
SD = Standard Deviation.  
P95 = 95<sup>th</sup> percentile.

Source: Hilbig et al., 2002.



Table 3-31. Percentage of Subjects Consuming Beverages and Mean Daily Beverage Intakes (mL/day) for Children With Returned Questionnaires

Age at Questionnaire Actual Age (Months)	6 Months	9 Months	12 Months	16 Months	20 Months	24 Months	6-24 Months <sup>a</sup>
N <sup>b</sup>	677	681	659	641	632	605	585 <sup>c</sup>
Human Milk <sup>d</sup>	30	19	11	5	3	0	-
Infant Formula <sup>e</sup>							
% <sup>d</sup>	68	69	29	4	2	0	67 <sup>g</sup>
mL/day <sup>f</sup>	798 ± 234	615 ± 328	160 ± 275	12 ± 77	9 ± 83	-	207 ± 112
Cows' Milk <sup>e</sup>							
% <sup>d</sup>	5	25	79	91	93	97	67 <sup>g</sup>
mL/day <sup>f</sup>	30 ± 145	136 ± 278	470 ± 310	467 ± 251	402 ± 237	358 ± 225	355 ± 163
Formula and Cows' Milk <sup>e</sup>							
% <sup>d</sup>	70	81	88	92	94	98	67 <sup>g</sup>
mL/day <sup>f</sup>	828 ± 186	751 ± 213	630 ± 245	479 ± 248	411 ± 237	358 ± 228	562 ± 154
Juice and Juice Drinks							
% <sup>d</sup>	55	73	89	94	95	93	99 <sup>h</sup>
mL/day <sup>f</sup>	65 ± 95	103 ± 112	169 ± 151	228 ± 166	269 ± 189	228 ± 172	183 ± 103
Water							
% <sup>d</sup>	36	59	75	87	90	94	99 <sup>h</sup>
mL/day <sup>f</sup>	27 ± 47	53 ± 71	92 ± 109	124 ± 118	142 ± 127	145 ± 148	109 ± 74
Other Beverages <sup>i</sup>							
% <sup>d</sup>	1	9	23	42	62	86	80 <sup>h</sup>
mL/day <sup>f</sup>	3 ± 18	6 ± 27	27 ± 71	53 ± 109	83 ± 121	89 ± 133	44 ± 59
Total Beverages mL/day <sup>e,d,j</sup>	934 ± 219	917 ± 245	926 ± 293	887 ± 310	908 ± 310	819 ± 299	920 ± 207
<sup>a</sup>	Cumulative number of children and percentage of children consuming beverage and beverage intakes for the 6 through 24 month period.						
<sup>b</sup>	Number of children with returned questionnaires at each time period.						
<sup>c</sup>	Number of children with cumulative intakes for six-through 24 month period.						
<sup>d</sup>	Percentage of children consuming beverage.						
<sup>e</sup>	Children are not included when consuming human milk.						
<sup>f</sup>	Mean ± standard deviation of beverage intake. Converted from ounces/day; 1 fluid ounce = 29.57 mL.						
<sup>g</sup>	Percentage of children consuming beverage during six-through 24 month period. Children who consumed human milk are not included.						
<sup>h</sup>	Percentage of children consuming beverage during six-through 24 month period.						
<sup>i</sup>	Other beverages include non juice beverages (e.g., carbonated beverages, Kool-Aid).						
<sup>j</sup>	Total beverages includes all beverages except human milk.						
Source:	Marshall et al., 2003a.						



**Table 3-32. Mean ( $\pm$  Standard Deviation) Daily Beverage Intakes Reported on Beverage Frequency Questionnaire and 3-day Food and Beverage Dairies**

Beverage	Age													
	6 months (N = 240)				12 months (N = 192)				3 years (N = 129)				5 years (N = 112)	
	Questionnaire mL/day <sup>a</sup>	Diary mL/day <sup>a</sup>	% <sup>b</sup>	Questionnaire mL/day <sup>a</sup>	Diary mL/day <sup>a</sup>	% <sup>b</sup>	Questionnaire mL/day <sup>a</sup>	Diary mL/day <sup>a</sup>	% <sup>b</sup>	Questionnaire mL/day <sup>a</sup>	Diary mL/day <sup>a</sup>	% <sup>b</sup>	Questionnaire mL/day <sup>a</sup>	Diary mL/day <sup>a</sup>
Human Milk	204 $\pm$ 373	195 $\pm$ 358	28.0	9 $\pm$ 21	56 $\pm$ 225	12.6	NA <sup>c</sup>	NA	-	NA	NA	-	NA	NA
Infant formula	609 $\pm$ 387	603 $\pm$ 364	85.8	180 $\pm$ 290	139 $\pm$ 251	37.0	NA	NA	-	NA	NA	-	NA	NA
Cow's milk	24 $\pm$ 124	24 $\pm$ 124	6.7	429 $\pm$ 349	408 $\pm$ 331	90.4	316 $\pm$ 216	358 $\pm$ 216	100	319 $\pm$ 198	325 $\pm$ 177	98.2	319 $\pm$ 198	325 $\pm$ 177
Juice/juice drinks	56 $\pm$ 124	33 $\pm$ 59	57.5	151 $\pm$ 136	106 $\pm$ 101	92.2	192 $\pm$ 169	198 $\pm$ 169	96.9	189 $\pm$ 169	180 $\pm$ 163	95.5	189 $\pm$ 169	180 $\pm$ 163
Liquid soft drinks	6 $\pm$ 68	0 $\pm$ 0	1.3	9 $\pm$ 30	3 $\pm$ 15	20.9	62 $\pm$ 71	74 $\pm$ 101	74.2	74 $\pm$ 95	101 $\pm$ 121	82.1	74 $\pm$ 95	101 $\pm$ 121
Powdered soft drinks	0 $\pm$ 18	0 $\pm$ 0	0.4	12 $\pm$ 47	3 $\pm$ 18	10.5	62 $\pm$ 115	47 $\pm$ 101	51.2	74 $\pm$ 124	47 $\pm$ 95	52.7	74 $\pm$ 124	47 $\pm$ 95
Water	44 $\pm$ 80	30 $\pm$ 53	61.7	127 $\pm$ 136	80 $\pm$ 109	84.9	177 $\pm$ 204	136 $\pm$ 177	95.3	240 $\pm$ 242	169 $\pm$ 183	99.1	240 $\pm$ 242	169 $\pm$ 183
Total	940 $\pm$ 319	896 $\pm$ 195	100	905 $\pm$ 387	804 $\pm$ 284	100	795 $\pm$ 355	816 $\pm$ 299	100	896 $\pm$ 399	819 $\pm$ 302	100	896 $\pm$ 399	819 $\pm$ 302

<sup>a</sup> Mean  $\pm$  standard deviation of all subjects. Converted from ounces/day; 1 fluid ounce = 29.57 mL.  
<sup>b</sup> Percent of subjects consuming beverage on either questionnaire or diary.  
<sup>c</sup> NA = not applicable.  
N = Number of observations.  
Source: Marshall et al., 2003b.



Table 3-33. Consumption of Beverages by Infants and Toddlers (Feeding Infants and Toddlers Study)

Beverage category	Age (months)											
	4-6 (N = 862)		7-8 (N = 483)		9-11 (N = 679)		12-14 (N = 374)		15-18 (N = 308)		19-24 (N = 316)	
	Consumers % <sup>a</sup>	Mean ± SD mL/day <sup>b</sup>	Consumers % <sup>a</sup>	Mean ± SD mL/day <sup>b</sup>	Consumers % <sup>a</sup>	Mean ± SD mL/day <sup>b</sup>	Consumers % <sup>a</sup>	Mean ± SD mL/day <sup>b</sup>	Consumers % <sup>a</sup>	Mean ± SD mL/day <sup>b</sup>	Consumers % <sup>a</sup>	Mean ± SD mL/day <sup>b</sup>
Total milks <sup>e</sup>	100	778 ± 257	100	692 ± 257	99.7	659 ± 284	98.2	618 ± 293	94.2	580 ± 305	93.4	532 ± 281
100% juice <sup>d</sup>	21.3	121 ± 89	45.6	145 ± 109	55.3	160 ± 127	56.2	186 ± 145	57.8	275 ± 189	61.6	281 ± 189
Fruit drinks <sup>e</sup>	1.6	101 ± 77	7.1	98 ± 77	12.4	157 ± 139	29.1	231 ± 186	38.6	260 ± 231	42.6	305 ± 308
Carbonated	0.1	86 ± 0	1.1	6 ± 9	1.7	89 ± 92	4.5	115 ± 83	11.2	157 ± 106	11.9	163 ± 172
Water	33.7	163 ± 231	56.1	174 ± 219	66.9	210 ± 234	72.2	302 ± 316	74.0	313 ± 260	77.0	337 ± 245
Other <sup>f</sup>	1.4	201 ± 192	2.2	201 ± 219	3.5	169 ± 166	6.6	251 ± 378	12.2	198 ± 231	11.2	166 ± 248
Total beverages	100	863 ± 254	100	866 ± 310	100	911 ± 361	100	1,017 ± 399	100	1,079 ± 399	100	1,097 ± 482

<sup>a</sup> Weighted percentages, adjusted for over sampling, nonresponse, and under representation of some racial and ethnic groups.  
<sup>b</sup> Amounts consumed only by those children who had a beverage from this beverage category. Converted from ounces/day; 1 fluid ounce = 29.57 mL.  
<sup>c</sup> Includes human milk, infant formula, cow's milk, soy milk, and goat's milk.  
<sup>d</sup> Fruit or vegetable juices with no added sweeteners.  
<sup>e</sup> Includes beverages with less than 100% juice and often with added sweeteners; some were fortified with one or more nutrients.  
<sup>f</sup> "Other" beverages category included tea, cocoa and similar dry milk beverages, and electrolyte replacement beverages for infants.  
 N = Number of observations.  
 SD = Standard deviation.

Source: Skinner et al., 2004.



Table 3-34. Pool Water Ingestion by Swimmers

Study Group	Number of Participants	Average Water Ingestion Rate (mL/45-minute interval)	Average Water Ingestion Rate (mL/hour) <sup>a</sup>
Children <16 years old	41	37	49
Males <16 years old	20	45	60
Females <16 years old	21	30	43
Adults (>18 Years)	12	16	21
Men	4	22	29
Women	8	12	16

<sup>a</sup>      Converted from mL/45 minute interval.

Source: Dufour et al., 2006.