Review Article

Advances and gaps in recommendations for adequate water intake in China

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Water is essential for life survival and development. It plays a pivotal role in metabolic function, modulates normal osmotic pressure, maintains the electrolyte balance, and regulates body temperature. Adequate water intake is necessary for optimal hydration—both excessive and insufficient water consumption can have adverse effects on health. Water requirements among people vary based on various factors such as gender, age, physical activity, dietary factors, ambient temperature, and renal concentrating capacity. In recent years, water intake guidelines have been developed in some countries and by some organisations. Even in China, it is important to develop such guidelines considering specific dietary habits, height of people, and environmental factors. In 2013, guidelines for adequate water intake were developed in China, but the scope was somewhat limited; there are still specific challenges in formulating such recommendations. Future water-related studies should focus on surveying water intake among infants and toddlers, older adults, and pregnant and lactating women. Moreover, additional studies should be conducted to elucidate water intake among adults and adolescents in different regions and seasons, and the association between water intake and related diseases should also be investigated. It is imperative to transform the results of scientific research into action plans for water-related health education so as to inform and evaluate pertinent public health programmes.

Key Words: water, water intake, hydration, dietary habits, physical activity

INTRODUCTION

Water is the main component of tissues in the human body and is essential for the survival and development of life. It plays roles in metabolism, modulates normal osmotic pressure, maintains the electrolyte balance, and regulates body temperature.[1] Both excessive and insufficient intake of water can have adverse effects on health. Dehydration may reduce cognitive performance and physical activity; moreover, it can increase the risks of urinary system and cardiovascular diseases.[2-7] Water requirements depend on various factors such as gender, age, physical activity, dietary factors, environment temperature, and renal concentrating capacity.[1] It is thus challenging to establish a RDA; thus, it is key to develop recommendations for adequate water intake. Guidelines for adequate water intake have been developed in a few countries (e.g. the United States, Canada, and Australia) and developed by a few organisations (e.g. the European Food Safety Authority and WHO).[8-14] Even in China, it has become pivotal to develop such guidelines considering diverse dietary habits, height of people, altitudes, and environmental factors. In 2013, guidelines for adequate water intake were proposed in China, but the scope is somewhat limited and there are still specific challenges in formulating such recommendations.[1]

This review focuses on water intake in China and is divided in the following six sections: physiological functions of water and effects of hydration on human health, establishment of a reference value for adequate water intake, methods to develop guidelines for adequate water intake, recommendations for adequate water intake in some countries and organisations, recommendations for adequate water intake in China, and future prospects and applications.

Physiological functions of water and effects of hydration on human health

Physiological functions of water

Water has many physiological functions in the human body and is the largest constituent of tissues. In metabolic processes, it accelerates nutrient absorption and transport, plays roles in nutrient metabolism and physiological chemical reactions, and assists in metabolic waste

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excretion through urination, perspiration, and expiration. Energy generated during metabolism can be absorbed by water to avoid a rapid increase in body temperature. In addition, evaporation of water in the form of sweat from the skin surface is an important way of maintaining body temperature. Mucus in the digestive, respiratory, and genitourinary systems, which is formed by the combination of water and sticky molecules, is known to buffer, lubricate, and protect muscles, organs, joints, and tissues.[1]

Effects of hydration on human health

Dehydration, as a consequence of inadequate water intake or excessive water loss, can adversely affect health, and the level of dehydration often depends on the degree of water deficiency. If the loss of body fluid exceeds 1% of body weight, plasma osmotic pressure increases, causing thirst and reduced physical activity.[1] Further, if the loss reaches 2%–4% (i.e. mild dehydration), urine volume decreases, urine specific gravity increases, and work efficiency reduces; if the loss reaches 4%–8% (i.e. moderate dehydration), the skin, mouth, and tongue become dry. If the loss of body fluid exceeds 8% (i.e. severe dehydration), the symptoms of fever, irritability, and stupor become evident, and if the loss exceeds 10%, body temperature increases and blood pressure and skin elasticity decrease, which can be life-threatening. Finally, if the loss of body fluid exceeds 20%, it can result in death.[15] Some studies have reported that dehydration can be induced by heat stress, extensive physical activities, water deprivation, or diuretics, potentially impacting the cognitive performance and mood of an individual.[16,17] In China, a self-control study involving young adults revealed that dehydration due to water deprivation had deleterious effects on short-term memory, attention, and moods related to vigour and esteem-related affect; in addition, water supplementation improved short-term memory, attention and reaction, and moods related to fatigue and total mood disturbance.[18] Dehydration also decreased muscle endurance, recovery after physical activities, and subsequent performance.[19-21] Moreover, dehydration and elevated sodium levels have been reported to stimulate inflammatory signalling in endothelial cells and promote atherosclerosis, in addition to increasing the risks of cardiovascular and urinary system diseases.[4,5]

Acute water intoxication, as the consequence of excessive water intake, is relatively rare in the general population, but its particularly prevalent in patients with some illnesses, such as kidney and liver diseases and congestive heart failure.[1] Water intoxication, along with the symptoms of brain cell swelling, cerebral oedema, and increased intracranial pressure, can cause headache, nausea, and memory loss and can even lead to intellectual disability, trance, coma, convulsions, and death.

Considering the aforementioned physiological functions of water and the effects of water intake on health, it is necessary to explore water requirements.

Establishment of a reference value for adequate water intake

Water requirements are influenced by many internal and external factors. Water is gained through drinking, food, and metabolism, and its excreted in the form of urine through the urinary system, sweat through the skin surface, breath through the respiratory system, and faeces through the gastrointestinal system (Table 1).[1] The inner balance of water metabolism affects water requirements. In general, water input and output are dynamically balanced, with both being maintained at approximately 2500 mL.[1] However, the proportion of water input and output highly depends on different circumstances. With regard to internal factors, water requirements differ among individuals depending on not only gender, age, and body surface area but also physical activity, body temperature, and other specific internal factors. In infants aged 0–6 months, water accounts for approximately 80% of body weight. The percentage gradually reduces with an increase in age. In adults, water accounts for approximately 60%–70% of body weight, and in older adults, the percentage gradually reduces even further with a reduction in muscle tissues.[1] In addition, discrepancies are evident between men and women: compared with men, women have less water in their bodies. Body surface area and temperature are also key factors influencing water requirements; they affect perspiration levels depending on the intensity and duration of physical activity and ambient temperature and humidity.[1] Perspiration helps in maintaining a constant body temperature—people release sweat to expel heat while performing physical activities. In addition to environment temperature and humidity, sweat volume is related to the amount, intensity, and duration of physical activities. The average volume of sweat can be as high as 4.5 L after 4 h of long-distance running training at 25°C–35°C, which increases the proportion of skin sweating to water loss.[22] Differences in dietary patterns and the energy ratio of macronutrients also affect the amount and proportion of water intake and loss. During food digestion, absorption, and metabolism, metabolic water is produced. Metabolic water (i.e. the water produced during the metabolism of proteins, fats, and carbohydrates) accounts for approximately 12% of body water content. According to the formula proposed by Campbell and Grandjean in 1928, a positive linear relationship exists between metabolic water and oxidation of the aforementioned three major nutrients.[23] The amount of metabolic water produced by the metabolism of each gramme of protein is 0.42 mL (1.07 mL and 0.6 mL for the metabolism of fats

Table 1. Inner balance of water metabolism for adults

Source of water	Amount (mL)	Discharge of water	Amount (mL)
Water from beverages	1200	Urine (Urinary system)	1500
Water from food	1000	Sweat (Skin)	500
Metabolic water	300	Breath (Respiratory system)	350
		Feces (Digestive system)	150
Total	2500	Total	2500

and carbohydrates, respectively).[23] With regard to external factors, at higher altitudes such as plateau regions, oxygen content in the air decreases and pulmonary ventilation volume increases; these changes cause an increase in water loss. The hypoxic plateau environment alters the internal water balance mainly by increasing urinary sodium excretion and dehydration. Therefore, to promote physiological adaptation to the hypoxic environment in plateau regions, it is recommended to consume sufficient nutrients and water containing an adequate amount of electrolytes (particularly sodium).[1] Further, at high temperatures, water evaporation from the skin surface increases; consequently, the body becomes prone to dehydration. A high-temperature and high-humidity environment increases body temperature and therefore sweat secretion, which may result in dehydration.[1] Dehydration leads to haemoconcentration, low haematocrit, increased heart rate and body temperature, decreased urine output, and other physiological and biochemical changes. Humidity mainly affects the processes of perspiration and the metabolism of water and salt. In a high-temperature and high-humidity environment, heat stroke can easily occur.[1]

Considering these influencing factors, numerous limitations have obstructed the development of recommendations for water intake. It is perhaps impossible to establish a set of recommendations that meet all requirements.[24] Even Grandjean stated in their 2009 study that estimated average requirements and a RDA for water could not be established.[25] Therefore, guidelines for adequate water intake have been developed by only a few organisations and in a few countries.

Methods to develop guidelines for adequate water intake

In recent years, many countries have proposed recommended values of adequate water intake based on data collected through water intake surveys. When deriving this value, some countries have even considered factors such as renal concentrating function and the relationship between energy consumption and water metabolism.

Calculating water requirements based on water loss and kidney function

Water loss can occur through the kidney, skin, lung, and intestinal tract. Generally, urination is the main mode of water loss (1500 mL, 60%), followed by sweating (500 mL, 20%), breathing (350 mL, 14%), and defaecating (150 mL, 6%).[1] However, the amount and proportion of water loss vary with the type and intensity of physical activity, temperature, and humidity; thus, more factors should be considered when calculating water requirements.

The water balance in the body is regulated by the thirst centre, renal function, and antidiuretic hormones secreted by the posterior lobe of the pituitary. The kidneys regulate the urine volume through the dilution and concentration of urine, thereby affecting the water balance and hydration state. Therefore, renal function should be considered when determining water requirements.[1]

Using data from water intake surveys as a reference to determine adequate water intake

Data on the amount of water intake comprise one of the most important reference values for establishing a recommendation for water adequate intake; such data can be collected through water intake surveys. Choosing an appropriate method to conduct water intake surveys is of great practical significance for obtaining accurate and representative data. The generally accepted methods to conduct water intake surveys include a 7-day fluid-specific diary (*Liq.In*[7]), the weighing method combined with the food composition table, weighing method, duplicate portion method combined with chemical analysis method, and administering food frequency questionnaires (FFQs). The most accurate method to survey daily drinking water intake is the *Liq.In*[7] and to survey water intake from foods is the weighing method, duplicate portion method combined with chemical analysis method.

Methods to survey daily drinking water intake

Liq.In[7]: The items in this diary are recorded at eight time points: before breakfast, during breakfast, during brunch, during lunch, during lunch and dinner, after dinner, and night. The diary covers an array of beverages such as packaged drinking water, natural mineral water, purified drinking water, natural spring water, natural drinking water, tube water, boiled water, fruit/vegetable juices and beverages, protein beverages, carbonated beverages, beverages for special uses, and tea. The scenario and place are recorded, such as before or after performing a physical activity or at home/school. The amount is recorded in millilitres or grammes, and additives in water, such as sugar, are also documented. To estimate water intake more accurately, participants are encouraged to use similar containers for water intake; calibrated cups are provided to them, and they are asked to refer to a photographic booklet of standard containers used to consume water or beverages. Some fluid intake surveys in China and other nations have found the *Liq.In*[7] method to be valid given its accuracy and reliability.[26,27] This method is suitable for investigating water intake by an individual. The advantage is that the data obtained from the survey are more accurate and relatively representative, whereas the disadvantage is that it takes a long time to ensure compliance among respondents.

The American Drinking Water Quantity Survey employed the *Liq.In*[7] method; participants were asked to record their drinking behaviour, including the amount of water intake per hour, place of water intake, and type of water consumed. However, the period of water intake was not recorded; further, more specific types of beverages could not be studied in detail.[28]

In China, water intake surveys are uncommon. A survey of 1483 adults and 5914 primary and middle school students from four cities used the *Liq.In*[7] method to estimate daily drinking water intake. The results revealed that approximately one-third of adults consumed <1200 mL water/day. The main sources of water intake were tube water and boiled water.[26,29] In a survey that employed the *Liq.In*[7] method and included 68 young adult men, cups to the nearest 10 mL were distributed to participants, and it was found that nearly three-quarters of young adult men did not meet the adequate water intake recommendation (1700 mL) in China.[30] In another survey that used the *Liq.In*[7] method and included 156 young adults, cups to

the nearest 5 mL were used to estimate the amount of water intake, and only 18.8% of men and 18.4% of young adult women met the adequate water intake recommendation (men: 1700 mL, women: 1500 mL).[31] In 2016, 2233 individuals aged 4–9, 10–17, and 18–55 years participated in a survey; the volumes and sources of total fluid intake were collected using the *Liq.In*[7] record, assisted by a photographic booklet of standard fluid containers; the results showed that about one-third of children and one-quarter of adolescents and adults reached the adequate intake.[32]

Other similar methods used to assess water intake include maintaining a 5-, 3-, 2-, and 1-day fluid-specific diaries.

Twenty-four-hour fluid-specific recall: In this method, participants recollect their water intake behaviour on the day before the survey (or 24 h before the last meal during the survey), including the time, type, place, and quantity of water intake. The advantage of this method is that completing the questionnaire is simple, easy, and quick, whereas the disadvantage is that it relies on the memory of participants, making it unsuitable for children and elderly people. Data obtained using the method has a memory bias, and its accuracy is relatively low.[33]

Methods to survey water intake from foods

Twenty-four-hour dietary recall: This is one of the most widely used methods in nutrition epidemiology. It is also a subjective, retrospective method and is conducted through face-to-face or telephone interviews or online retrospective self-report using computer programmes. Study participants must precisely recall, describe, and quantify the consumption of foods and beverages during the previous 24 h, right from the intake of the first food/beverage after getting up in the morning to that of the last food/beverage before going to bed or later at night. The information captured includes the types of food and beverages, cooking and process method, net quantity of consumption, brands of packaged food, and multivitamin and food supplements as well as the time and place of consumption. Food and photographic models are used to help participants recall pertinent information.[34] In the American National Health and Nutrition Examination Survey 2005–2010, information on water intake was collected through two nonconsecutive 24-h dietary recalls.[35] In the Dutch National Food Consumption Survey 2007–2010, 24-h dietary recalls were used to collect information on food and water intake.[36] The disadvantage of this method is that the survey content is not targeted and less information is present on water intake.

FFQs: There are three types of FFQs: qualitative, quantitative, and semiquantitative. Qualitative FFQs only collect information on the frequency of food and water intake in a given period; they do not capture information on the food amount. Quantitative FFQs require participants to record the amount of food and water intake, estimated with reference to food and photographic models. Semiquantitative FFQs are the most commonly used; questions on food and water consumption frequency are to be answered, for example, as never or rarely and number of times in a month, week, or day. In 2010, Veitch et al used quantitative FFQs to obtain estimates of water intake among 747 adolescents in the Netherlands.[37]

Weighing method, duplicate portion method combined with chemical analysis method: In this method, all foods consumed by participants are weighed, and duplicate samples are collected for 3 consecutive days. Water intake from each type of food is analysed using methods such as direct drying, vacuum drying, infrared drying, distillation, spectrophotometry, and chromatography. This method can be applied to most foods, dishes, snacks, porridge, soups, and others. Its advantages are that it is highly accurate, reliable, and suitable for most food types,[38] whereas the disadvantages are that its complex and measurements need to be made in a laboratory. Time, manpower, and economic costs are high, making it challenging to apply the method to a large sample population.

In China, several surveys used this method to assess water intake from foods.[30-31,39] The results showed that water intake from foods was 1157 mL among adults, and the median ratio of water intake from foods accounted for 41.4% of the total water intake.[40] Water intake from foods among young adult men was 1211 mL, accounting for 47.4%.[30]

Weighing method combined with food composition table: In this method, the actual food intake is weighed on an electronic scale, and the water present in every 100 g of food is determined and recorded according to a food composition table. Water intake from foods (mL) = Weight of food consumed (100 g) × water from food (mL/100 g).[30,39] This method is generally suitable for calculating water intake from fruits and packaged foods with nutritional labels or millilitres of liquid. The advantages of this method are that it is easy to implement and involves the use of simple survey tools, making its application feasible on a large scale, whereas the disadvantage is that it cannot be used to investigate water intake from dishes after cooking.

Using the relationship between energy consumption and water requirement to calculate adequate water intake

According to the RDA in the United States in 1989, the water requirement was 1.5 mL/kcal of energy consumption, which can be used to calculate adequate water intake.[1,8] However, perspiration level, physical activity, and other factors need to be considered when developing guidelines for adequate water intake; moreover, the specific needs of young children, pregnant and lactating women, and elderly people should not be neglected.

Establishing recommendations for adequate water intake to maintain a proper hydration state

The hydration state is determined by water intake and loss. Dehydration refers to deficient water intake, with the accompanying disruption of metabolic processes, which can be harmful to health.[30] The minimum water requirement is an amount that is equivalent to water loss and prevents the adverse effects of dehydration.[25] The recommendations for adequate water intake should ensure the maintenance of a proper hydration state. The hydration state can be judged based on urine, blood, tear, and saliva osmolality; urine colour; urinary specific gravity; body weight change; body fluid distribution; water intake quantity; and

some other related signs. The commonly used criteria for judging the dehydration state include the following: 24-h urine osmolality >500 mOsm/kg, morning urine osmolality >700 mOsm/kg, blood osmolality >290 mOsm/kg, tear osmolality >309 mOsm/kg, and urine specific gravity >1.020.[41-44] Body weight change is also commonly used to judge acute hydration: the degree of dehydration is positively correlated to the proportion of body weight change. In general, ≥2% body weight loss can be regarded as the dehydration state.[45] A reduction in urine volume is also indicative of the dehydration state.[46] Normally, urine is slightly transparent and yellow or white in colour; however, when water intake is insufficient, the colour gradually deepens. On the urine colour scale established by Professor Armstrong, some studies have reported that a score of >4 represents the dehydration state.[47,48] Moreover, salivary osmolality was reported to increase from 54 to 73 mOsm/kg when water intake was restricted for 48 h.[49] To explore the relationship between urination frequency and the hydration state, a study recruited 87 adults and divided them into groups depending on adequate hydration and dehydration state according to urine specific gravity. The results showed that the 24-h urination frequency of participants in the adequate hydration state group was more than that in the dehydration state group (5 ± 2 vs 3 ± 1).[50] Moreover, a survey involving 68 young adult men in China revealed that the 24-h urination frequency in the dehydration state was significantly lower than that in the adequate hydration state (7 ± 2 vs 5 ± 2).[30] In addition, a study adopted the receiver operating characteristic curve method to determine how to judge the dehydration state using the amount of water intake; the results suggested that participants had an adequate hydration state when water intake was ≥2582 mL.[30]

Calculating adequate water intake using a formula, with body weight, body surface area, and other related factors as coefficients

Body weight, body surface area, and other related factors influence the water requirements of an individual. Adults should consume 40 mL of water per kilogramme of body weight.[51] In infants and young children, the water metabolism rate and body surface area are relatively large; thus, they are more prone to dehydration. Therefore, when calculating water requirements according to body weight, the amount should be accordingly adjusted.[1]

Establishing recommendations for adequate water intake for preventing illnesses

A new index, Proposed Intakes for Preventing Noncommunicable Chronic Diseases, was introduced in Chinese Dietary Reference Intakes (2013) compiled by the Chinese Nutrition Society.[1] The significance of proposing this index was to prevent noncommunicable chronic diseases. Rational intake is no longer just to meet physiological requirements but to further prevent and reduce the incidence rate of chronic diseases. When the intake of some nutrients among the non-communicable chronic diseases (NCD)susceptible population reaches proposed intakes (PI), the risk of NCD can be reduced. Dehydration due to insufficient water intake or excessive water loss can be harmful to health and increase the risks of cardiovascular and urinary system diseases. Preventing or decreasing the risks of such conditions is essential and should be considered when establishing recommendations for adequate water intake. However, the information available in studies that have explored the association between the hydration state and some specific diseases is far from conclusive. Thus, future studies should explore the relationship among water intake, hydration state, and diseases to generate more evidence.

Recommendations for adequate water intake in some countries and organisations

The recommendations for adequate water intake have been developed by WHO, the United States, the European Food Safety Authority, and some other nations and organisations (Table 2).[1]

WHO: To avoid dehydration (24-h urine osmolality >500 mOsm/kg), as per WHO, the daily total water intake for sedentary men and women should be 2900 mL and 2200 mL, respectively. In a high-temperature environment, the daily recommended total water intake for adults is 4500 mL; for pregnant women, 4800 mL is recommended, and lactating women should consume 3300 mL.[8] (Daily total water intake = adequate daily drinking water intake + adequate daily water intake from foods).

European Food Safety Authority: In 2010, the European Food Safety Authority suggested that the daily adequate drinking water intake for adults should be within 1400 mL/day–12 L/day depending on environment temperature and physical activity. Based on the data from water intake surveys and adequate urine osmolality to maintain a proper hydration state, it is proposed that the daily total water intake for adults should be 2500 mL for men and 2000 mL for women.[9]

Other countries: In the United States, according to the water intake data from National Health and Nutrition Examination Survey III, the daily total water intake for men and women (aged 19–30 years) should be 3700 mL and 2700 mL, respectively; these values are in accordance with the recommendations in Canada.[8] In a joint proposal issued by the National Health and Medical Research Council of Australia and the Ministry of Health in New Zealand, it was suggested that the daily total water intake should be 3400 mL for men and 2800 mL for women, with the daily adequate drinking water intake being 2600 mL and 2100 mL, respectively.[10] In a water branch conference of the International Society for Life Sciences held in North America in 2011, it was proposed by the International Life Sciences Institute that the minimum daily total water intake should be 1000–3100 mL for a sedentary adult under moderate climatic conditions.[1] In Belgium, the recommended daily total water intake for adults is 2500 mL, and the daily adequate drinking water intake is 1500 mL.[11] In Denmark, Finland, Norway, and Sweden, in 2004, the recommended daily adequate drinking water intake for adults was proposed to be 1500 mL; lactating women are advised to drink an additional 600–700 mL.[12] The UK Food Standards Agency and the British Dietetic Association recommended that the daily adequate drinking water intake should be 1500–2500 mL under moderate climate conditions.[13]

Table 2. Adequate water intakes in United State, Australia/New Zealand and Europe (L/d)

Age (year)	United State		Australia/New Zealand		Europe
	Daily total adequate water intakes†	Daily adequate drinking water intakes‡	Daily total adequate water intakes†	Daily adequate drinking water intakes‡	Daily total adequate water intakes†
0~	0.68[1]	---	0.7[1]	---	100~190[1,2]
0.5~	0.84	---	0.8	---	0.8~1.0
1~	1.3		1.4	1.0	1~:1.1~1.2 2~:1.3
4~	1.7		1.6	1.2	1.6
9~					
Boys	2.4	1.8	2.2	1.6	2.1
Girls	2.1	1.6	1.9	1.4	1.9
14~					
Boys	3.3	2.6	2.7	1.9	2.5
Girls	2.3	1.8	2.2	1.6	2.0
19~					
Men	3.7	3.0	3.4	2.6	2.5
Women	2.7	2.2	2.8	2.1	2.0

†Daily total adequate water intakes include water from beverages and water from food.
‡Daily adequate drinking water intakes only include water from beverages:
(1) Purely breast-fed infants do not need extra water
(2) Unit: mL/kg bw

Recommendations for adequate water intake in China

Necessity of developing guidelines for adequate water intake in China

Water requirements can considerably vary and are complex. It is inappropriate to develop guidelines for adequate water intake that are applicable to all nations. Thus, even for China, it is necessary to develop specific guidelines for adequate water intake considering specific dietary habits, height of people, altitudes, and other environmental conditions.

Dietary habits: The water intake behaviour of individuals, such as the type of beverage, differs between China and Western countries. Water content in beverages varies: tea and coffee consist of 99.5% water, whereas skim milk, 2% fat milk, and whole milk consist of 91%, 89%, and 87% water, respectively.[1,25] In addition, in case of the residents of China, dietary compositions and cooking processes are unique. In China, the daily diet is mainly composed of plant-based foods, which have a higher water content, and the cooking methods chiefly involve steaming, stewing, and stir frying, all of which retain more original water content in foods compared with European cooking methods. In Europe and the United States, the proportion of water obtained from daily foods accounts for approximately 20%,[52] while it is almost 44% in China.[40] Due to different dietary compositions in China, the contribution of metabolic water to total water intake is also different from that in other nations. Further, the dietary structures show discrepancies in different regions of China, affecting water intake. In a water intake survey in four cities in China, it was shown that the amount and proportion of water from soups accounting for the total water intake from foods among adults in Guangzhou (267 mL, 24.4%) and Chengdu (278 mL, 15.7%) were higher than those in Shanghai (133 mL, 9.0%) and Beijing (100 mL, 5.8%).[40]

Altitude and other environmental conditions: In China, landscapes markedly vary across its vast area: there are extensive alluvial plains in the East, high plateaus and broad grasslands in the North, and hills and low mountains in the South. Furthermore, there are two major rivers—Yellow River and Yangtze River—in the central east and a major mountain range in the west. The climate is mainly dominated by dry seasons and wet monsoons, leading to pronounced temperature differences between winter and summer. In the winter, northern winds coming from higher latitude areas are cold and dry; in the summer, southern winds from lower latitude areas are warm and moist.[53] The climate in China varies in different regions due to the highly complex topography. Altitude and other environmental conditions in China are different from those in other countries, thereby affecting water requirements.

Height differences: Due to genetic differences, the height of people varies between the Chinese and Europeans or North Americans. As height is directly proportional to body surface area, it may affect water requirements.[54]

Principles, methods, and procedures for developing guidelines for adequate water intake in China

Based on the data from water intake surveys, recommendations for adequate water intake were proposed considering age, gender, physical activity, dietary habits, environment, energy consumption, and renal concentrating capacity in China (Table 3).[1] However, there are specific challenges in formulating these recommendations.

Infants aged 0–6 months: Water accounts for a larger proportion of body weight. In addition, infants have a higher basal metabolic rate but an immature kidney system, which makes them prone to an water–electrolyte imbalance.[1] Thus, optimal water intake is important for infants. It is suggested that infants aged 0–6 months should be exclusively fed breast milk. In China, the breast milk intake of infants aged 0–6 months is approximately 750 mL/day. Water accounts for 85% of breast milk. Therefore, the total water intake for infants aged 0–6 months is 700 mL/day.[1]

Table 3. Adequate water intakes in China[1] (L/d)

Age (years)	Daily adequate drinking water intakes[†]		Daily total water adequate intakes[‡]	
0~6 months	---		0.7[2]	
7~12 months	---		0.9	
1~3 years	---		1.3	
4~6 years	0.8		1.6	
7~10 years	1.0		1.8	
	Boys/men	Girls/women	Boys/men	Girls/women
11~13 years	1.3	1.1	2.3	2.0
14~17 years	1.4	1.2	2.5	2.2
≥18 years	1.7	1.5	3.0	2.7
Pregnant women	---	1.7	---	3.0
Lactating women	---	2.1	---	3.8

[†]Daily adequate drinking water intakes only include water from beverages:
(1) Light physical activity in moderate climatic conditions
(2) Purely breast-fed infants do not need extra water
[‡]Daily total adequate water intakes include water from beverages and water from food

Infants aged 7–12 months: The daily breast milk intake is approximately 600 mL, and the amount of water obtained from other foods and beverages is 330 mL/day. Thus, the daily total water intake for infants aged 7–12 months is 900 mL.[1]

Toddlers (aged 1–2 years): The daily breast milk intake is approximately 530 mL. The energy obtained from other foods is approximately 550 kcal.[1] The water requirement for energy consumption is 825 mL (1.5 mL/kcal energy). Thus, the daily total water intake for toddlers aged 1–2 years is 1300 mL.[1]

Young children (aged 3 years): Considering the lack of water intake data, it is suggested that the daily total water intake for young children (aged 3 years) is 1300 mL, which is the same as that for toddlers aged 1–2 years.[1]

Children (aged 4–6 years): Water content in the body decreases with age among children and adolescents, but it is still higher than that in adults. Considering their vigorous metabolism, their body temperatures increase more easily during physical activity. Therefore, young children need to intake sufficient water to meet their body demands. Due to the lack of water intake data, the daily adequate drinking water intake for children aged 4–6 years was estimated by referring to data pertaining to adults. The daily adequate drinking water intake for children aged 4–6 years is 800 mL. Considering that their digestive ability is relatively weak, the suggested daily total water intake for children aged 4–6 years is 1600 mL. The calculation process is as follows: Daily adequate drinking water intake for children aged 4–6 years = Daily adequate drinking water intake for men × (average body weight for boys aged 4–6 years/average body weight for men aged 18–50 years) 0.75 × (1 + growth coefficient for boys aged 4–6 years) = 800 mL (Note: daily adequate drinking water intake for men, 1700 mL; average body weight for boys aged 4–6 years, 19.5 kg; average body weight for men aged 18–50 years, 66 kg; and growth coefficient for boys aged 4–6 years, 0.15).[1]

Older children and adolescents (aged 7–17 years): A survey involving 5868 children and adolescents conducted in four cities in China showed that the average daily drinking water intake was significantly higher for boys (1157 mL) than for girls (1026 mL). The average daily drinking water intake for boys aged 7–10, 11–13, and 14–17 years was respectively 953, 1134, and 1170 mL.[26] Based on these data, the following daily adequate drinking water intake guidelines are proposed: children aged 7–10 years: 1000 mL; boys aged 11–13 years: 1300 mL; girls aged 11–13 years: 1100 mL; boys aged 14–17 years: 1400 mL; and girls aged 14–17 years: 1200 mL. The recommended daily total water intake for these sex and age groups is 1800, 2300, 2000, 2500, and 2200 mL, respectively.[1]

Adults (aged ≥18 years): A survey involving 1483 adults aged 18–60 years showed that the average daily drinking water intake for men (1679 mL) was more than that for women (1370 mL). The average daily total water intake for all participants was 3035 mL.[39] Based on these data, considering energy consumption, physical activity, perspiration, and solute load, the recommended daily total water intake for men is 3000 mL and for women is 2700 mL, with the daily adequate drinking water intake being 1700 mL and 1500 mL, respectively.[1]

Elderly individuals: The daily total water intake for elderly people should be the same as that for adults. However, with an increase in age and decline of kidney function and water balance recovery, older adults are more prone to dehydration and should thus cultivate a habit of drinking plenty of water.[1]

Pregnant and lactating women: Pregnant women should drink an additional 300 mL of water to that consumed by nonpregnant women considering the needs of the foetus and the formation of amniotic fluid. Lactating women should drink an additional 1100 mL of water considering breast milk formation.[1] In China, data on water intake for pregnant and lactating women are insufficient. Using the data from other countries as a reference, the recommended daily total water intake for pregnant and lactating women was proposed to be 3000 mL and 3800 mL (daily adequate drinking water intake: 1700 mL and 2100 mL), respectively.[1]

Future prospects and applications

At present, most studies on water intake have solely investigated water intake behaviour, but the hydration state was not assessed based on related physiological indices. It is necessary to further objectively evaluate the hydration state by measuring urine osmolality, urine specific gravity,

and other similar indices. In addition, only the recommendations for adequate water intake for children, adolescents, and adults have been developed based on data pertaining to water intake among residents of corresponding age groups in China. The recommendations for adequate water intake among other age groups or physiological stages were proposed by referring to data pertaining to water intake among residents of corresponding age groups in other countries or by considering the relationship between energy consumption and water requirements. Thus, first, further surveys need to be conducted on breast milk intake and energy requirements for infants aged 0–2 years and on water intake for infants aged 3 years. More surveys should analyse the water intake behaviour of older adults and pregnant and lactating women. Additional data on water intake among people in different regions and during different seasons also should be generated.

Second, studies conducted abroad that have investigated the relationship between water intake, hydration state, and health have mainly focused on the aspects of cognitive ability, physical activity, and urinary system and cardiovascular diseases. In China, only few studies have explored the relationship between water intake, hydration state, and health, and they have focused on, for example, the effects of hydration on cognitive ability. It is thus pivotal to conduct more such studies; further, the focus should be expanded to different diseases, such as obesity, dyslipidaemia, diabetes, and metabolic syndrome. This should facilitate the estimation of water intake requirements for preventing and decreasing the risk of related illnesses.

Third, China is unique for many reasons, and there are specific challenges in formulating such recommendations. More studies need to be conducted to elucidate differences in the methodology used to establish recommendations in comparison with the recommendations in China. The recommendations for adequate water intake must be further developed based on more scientific evidence and by using appropriate methods.

Fourth, it is imperative to transform the results of scientific research on water intake into water-related health education, which can, in general, help raise awareness on the importance of water intake. This should help in urging people to consume sufficient water and maintain a suitable hydration state, eventually promoting health.

Finally, studies involving water intake surveys and exploration of water intake behaviour, hydration state, and health are useful to inform and evaluate pertinent public health programmes. National nutrition and health status are important indicators that reflect socioeconomic development, healthcare, and population characteristics of a country. In 1959, a comprehensive nutrition survey was conducted in China, which gradually covered health status. Up to now, five large-scale surveys have been conducted; these have become a part of national routine monitoring work in China.[55] In previous surveys, dietary intake was the key area of focus, and water intake behaviour was captured as additional information. Data on water intake was less, and the accuracy was insufficient. With an increase in the understanding of the importance of water, emergence of studies that are comprehensively exploring water intake, and improvement in water survey methodology, it can be considered to incorporate more targeted water intake survey methods into this national routine monitoring work. This should result in a more comprehensive understanding of the characteristics of drinking water behaviours among the residents of China, aid the assessment of the hydration state, facilitate the analysis of epidemic characteristics and change rule of related diseases, and finally promote the formulation of relevant policies and measures for disease prevention. Collectively, such measures should promote the health of the entire population.

Conclusions

Ensuring adequate water intake helps to maintain optimal hydration levels and ultimately promote health. Recommendations for adequate water intake need to be developed to guide residents to consume sufficient water. Although some organisations or countries have developed recommendations for adequate water intake, the scope has been somewhat limited. More surveys on water intake and more studies on hydration state and health should be conducted among different groups of population in order to generate comprehensive scientific data and evidence; this should help in further improvement and revision of pertinent recommendations. These measures should be useful to inform and evaluate related public health programmes.

AUTHOR DISCLOSURES

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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