# Advances and gaps in recommendations for adequate water intake in China

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**ABSTRACT**

Water is essential for life survival and development. Water is involved in metabolic function, modulates normal osmotic pressure, maintains electrolyte balance, and regulates body temperature. Both excessive water and insufficient water have negative effects on health, and adequate water intake is necessary for optimal hydration. Water requirements among people vary based on factors such as sex, age, physical activity, dietary factors, environment temperature, and kidney concentration capacity. In recent years, water intake guidelines have been developed in some countries and organizations. In China, however, it is still necessary to develop specific water intake guidelines due to the specific dietary habits, heights, and other environmental conditions. In 2013, adequate water intake guidelines were developed in China, but the scope was somewhat limited and there are still quite specific challenges in formulating such recommendations. Future water-related studies should focus on surveying water intake in infants and toddlers, older adults, and pregnant and lactating women. Furthermore, more studies on water intake of adults and adolescents in different regions and seasons are required, as are studies on the associations between water intake and related diseases. It is imperative to transform scientific theory into action in water-related health education and can be used to inform and evaluate public health programmes.

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

Water is the main component of the tissues in the human body and is essential for the survival and development of life. Water participates in the metabolism, modulates normal osmotic pressure, maintains electrolyte balance, and regulates body temperature.[1] Both excessive and insufficient intake of water have negative effects on health. Dehydration may reduce cognitive performance and physical activity and increase the risk of urinary and cardiovascular diseases.[2-7] Water requirements are affected by sex, age, physical activity, dietary factors, environment temperature, and kidney concentration capacity.[1] A recommended dietary allowance (RDA) could not be established, thus it is necessary to establish recommendations for adequate water intake. Adequate water intake have been developed in a few countries and organizations, such as the United States, Canada, Australia, the European Food Safety Authority, and the World Health Organization.[8-14] However, it is necessary to propose adequate water intake guidelines in China due to different dietary habits, heights, altitudes, and other environmental conditions. In 2013, adequate water intake was proposed in China,

but the scope is somewhat limited and there are still quite specific challenges in formulating such recommendations.[1]

This review focuses on water intake in China and is divided in the following six sections: first, the physiological functions of water and the effects of hydration on human health; second, the establishment adequate water intake as reference value for water intake for population; third, methods of developing adequate water intake guidelines; fourth, recommendations for adequate water intake in some countries and organizations; fifth, recommendations for adequate water intake in China; and finally, future prospects and applications.

## *Physiological functions of water and the effects of hydration on human health*

### Physiological functions of water

Water participates in many physiological functions of body. Water is the largest constituent of body tissues. In metabolic processes, water accelerates the absorption and transport of nutrients, participates in the metabolism of nutrients and the physiological chemical reaction, and assists in the excretion of metabolic waste through urination, sweat, and expiration. Energy generated during metabolism can be absorbed by water to avoid a rapid increase in body temperature. In addition, evaporation of water as sweat from the skin surface is an important way to maintain body temperature. Mucus contained in the digestive, respiratory, and genitourinary systems, which are formed by the combination of water and sticky molecules, buffers, lubricates, and protects muscles, organs, joints, and tissues.[1]

### Effects on human health

Water is essential for human survival. Both excessive and insufficient water intake have negative effect on health.

Dehydration, as the consequence of inadequate water intake or excessive water loss, does harm to health and vary depending on the degree of water deficiency. If the loss of body fluid exceeds 1% of body weight, plasma osmotic pressure increases, leading to thirst and reduced physical activity.[1] If the loss reaches 2%–4%, which indicates mild dehydration, urine volume decreases, urine-specific gravity increases, and work efficiency reduces. If the loss reaches 4%–8%, which indicates moderate dehydration, the skin, mouth, and tongue become dry. If the fluid loss exceeds 8%, which indicates severe dehydration, the symptoms of fever, irritability, and stupor are evident. If the fluid loss exceeds 10%, arise in body temperature and decline in blood pressure and skin elasticity occur, which can be life threatening. If the

fluid loss exceeds 20%, it can result in death.[15] Some studies showed that dehydration induced by heat stress, extensive physical activities, water deprivation, or diuretics may impair cognitive performances and mood.[16,17] In China, a self-control study among young adults showed that dehydration state induced by water deprivation has negative effects on the ability of short-term memory, attention, and mood of vigor and esteem-related affect; in addition, water supplementation improved the ability of short-term memory, attention and reaction, and mood of fatigue and TMD.[18] Dehydration also decreased muscle endurance, recovery after physical activities and subsequent performances.[19-21] Dehydration and elevated sodium stimulated inflammatory signaling in endothelial cells and promoted atherosclerosis, and increase the risk of cardiovascular diseases and urinary system diseases.[4,5]

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

In view of the above physiological functions and the impact of water intake on health, it is necessary to explore water requirement.

***Establishing adequate water intake as reference value for water intake for population***

Water requirements are influenced by many internal and external factors. Water is required through drinking water, water from food, and metabolic water, and is excreted as urine through the urinary system, sweat through the skin surface, breathe through the respiratory system, and feces through the digestive system (Table 1).[1] Inner balance of water metabolism affect water requirement. 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 varies highly depending on different circumstance. For individual internal factors, water requirements differ between different people in terms of not only sex, age, and body surface area but also physical activity, body temperature, and other individual internal factors. For babies aged 0 to 6 months, water accounts for approximately 80% of their body weight. The percentage gradually reduces with an increase in age. For adults, water accounts for approximately 60%–70% of body weight. For older adults, this percentage gradually reduces along with a reduction in muscle tissues.[1] Discrepancies are evident between the sexes: women have less water in their bodies than men do. Body surface area and body temperature

are also key factors influencing water requirements, which affect sweat depending on the intensity and duration of physical activity and ambient temperature and humidity.[1] In order to maintain a constant body temperature, people sweat to expel heat while doing physical activities. Sweat volume is related to the amount, intensity and duration of physical activities, and the temperature and humidity of the environment. The average sweating volume can reach 4.5 L after 4 hours of long-distance running training at 25-35℃, which increases the proportion of skin sweating to water loss.[22] Differences of dietary patterns and energy ratio of macronutrients also affect the amount and proportion of water intake and water loss. During food digestion, absorption, and metabolism, metabolic water produces. Metabolic water, referring to the water produced in the metabolic process of the three major nutrients (protein, fat, and carbohydrates), accounts for approximately 12% of body water content. According to the calculation formula of metabolic water, which was proposed by Campbell and Grandjean in 1928, a positive linear relationship exists between metabolic water and the oxidation of three major nutrients.[23] The metabolic water produced by each gram of protein is 0.42 mL (1.07 and 0.6 for fat and carbohydrates, respectively).[23] For external environmental factors, at higher altitudes such as plateau areas, the oxygen content in air decreases and pulmonary ventilation volume increases; these changes lead to an increase in water loss. The hypoxic plateau environment alters the internal water balance—mainly thorough the increased excretion of urinary sodium and dehydration. Therefore, on plateaus, it is beneficial to consume sufficient nutrients and water containing an adequate amount of electrolytes (especially sodium), which can promote physiological adaptation to the hypoxic environment.[1] At high temperatures, water evaporation from the skin surface increases; as a result, the body is prone to dehydration. An environment of high temperature and high humidity increases body temperature and therefore sweat secretion, which may result in dehydration.[1] Dehydration leads to hemoconcentration, low hematocrit, increased heart rate, increased 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]

In light of these influencing factors, numerous limitations obstruct the development of recommendations for water intake. It is perhaps impossible to establish a set of recommendations that meets all needs.[24] Grandjean concluded that estimated average requirements and a recommended dietary allowance (RDA) could not be established.[25]

Therefore, adequate water intake guidelines have been developed by only a few organizations and countries.

***Methods of developing adequate water intake***

In recent years, many countries have put forward recommended values of adequate water intake for population, based on the data of water intake surveys. Some countries also consider the factors of kidney concentration function, the relationship of energy consumption and water metabolism and so on, when adequate water intake was developed.

**Calculating water requirements based on water loss and kidney function**

There are four ways of water loss: kidney, skin, lung and intestinal tract. Generally, water loss in the form of urine through the kidney is the main way of water loss (1500 mL, 60%), followed by the form of sweat through the skin (500 mL, 20%), the form of breathing through lung (350 mL, 14%) and in the form of feces through intestinal tract (150 mL, 6%).[1] However, the amount and proportion of water loss vary with the differences of the type and intensity of physical activity, temperature and humidity of environment, thus, more factors should be taken into account when calculating water requirement.

The water balance in body is regulated by thirst center, renal function and antidiuretic hormone secreted by the pituitary nerve posterior lobe. Kidney can regulate the volume of urine through dilution and concentration of urine, and then affect body's water balance and hydration state. Therefore, renal function should be taken into account when calculating water requirement.[1]

**Using the data of water intake surveys as references to develop adequate water intake**

The data on the amount of water intake is one of the most important reference value for establishing the recommendation on water adequate intake, which can be obtained from water intake surveys. Choosing appropriate methods to conduct water intake surveys is of great practical significance for obtaining accurate and representative data. The generally accepted methods of water intake surveys include 7-day fluid-specific diary (*Liq.In*[7]), weighing method with the food composition table, weighing method, duplicate portion method combined with chemical analysis method, food frequency questionnaire and son on. The most accurate methods is 7-day fluid-specific diary (*Liq.In*[7]) for daily drinking water intake survey and weighing method, duplicate portion method combined with chemical analysis method for water intake from food.

Methods of survey on daily drinking water intake

7-day fluid-specific diary (*Liq.In*[7]): The items in this diary includes 8 time points: before breakfast, breakfast, brunch, lunch, during lunch and dinner, dinner, after dinner and night. The diary covers a variety of beverages: packaged drinking water, natural mineral water, purified drinking water, natural spring water, natural drinking water, tube water, boiled water, fruit/vegetable juices and beverage, protein beverage, carbonated beverage, beverage for special uses, tea and so on. The scene and place are recorded, such as before, after or doing physical activity, at home, at school, at and others. The amount is recorded in milliliters or grams. Additives in water, such as sugar, also need to be recorded. To estimate water intake more accurately, common utensils for water used by participants will be quantified; calibrated cups will be distributed to participants; a photographic booklet of standard water or beverages containers will be used as reference. Some surveys of fluid intake in China and other countries have found the *Liq.In*[7] method to be valid for accuracy and reliability.[26, 27] This method is suitable for investigating individual's water intake. The advantage is that the data obtained from the survey are more accurate and relatively representative. The disadvantage is that it takes a long time to ensure the compliance of the respondents.

In the American Drinking Water Quantity Survey (DWCS), the method of *Liq.In*[7] was used. The participants recorded their drinking behavior, including the amount of water intake per hour, the place of water intake, the type of water. However, the time period of water intake was not recorded and more specific types of beverages could not be identified in detail.[28]

In China, surveys on water intake are relatively less. In surveys with 1483 adults and 5914 primary and middle school students from 4 cities, method of *Liq.In*[7] was used to estimate daily drinking water. The results showed that about a third of adults had less than 1200 mL of water per day. The water intake of primary and secondary school students was lower compared with the students in American. The main sources of water intake were tube water and boiled water.[26,29] In a survey with 68 young adult men with *Liq.In*[7] method, cups to the nearest 10 mL were distributed to participants, and it was shown that nearly three-quarters of young adult men did not reach the recommendation on water adequate intake (1700 mL) in China.[30] In another survey with 156 young adults with *Liq.In*[7] method, 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 reached the recommendation on water adequate intake (men: 1700 mL, women: 1500 mL).[31] In 2016, 2233 participants aged 4-9, 10-17 and 18-55 years were included in a survey, the volumes and sources of TFI were collected by validated 7-day fluid

specific diary assisted by a photographic booklet of standard fluid containers. Results showed that about a third of children, and a quarter of adolescents and adults, reached the AI. [32]

Other similar methods used to assess water consumption include 5-day, 3-day, 2-day, and 1-day fluid-specific diary.

24-h fluid-specific recall: The participants recalled the behaviors of water intake on the day before the survey (or 24 hours before the last meal during survey), including the time, type, place and quantity of water intake. The advantage of this method is that it is simple and easy to fill out the questionnaire in a short time. The disadvantage is that it relies on the memory of the participants, so it is not suitable to be used among children and elderly people. The data obtained from the method has memory bias, and its accuracy is relatively low.[33]

Methods of survey on water intake from food

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

Food frequency questionnaire: There are three types of food frequency questionnaires (FFQs): qualitative, quantitative, and semiquantitative. Qualitative FFQs only collect the information on the frequency of food and water intake in a given period of time, but not information on the food amount. Quantitative FFQs require participants to provide the amount of food and water intake, which are estimated with reference to food models and photographic models. Semiquantitative FFQs are the most commonly used method; the analysis of food and water consumption frequency allows answers such as never, rarely, and the number of times

in one month, week, or day. In 2010, Veitch et al adopted the quantitative FFQ to obtain estimates of water intake among 747 adolescents in the Netherlands.[37]

Weighing method, duplicate portion method combined with chemical analysis method: All foods consumed by the participants are weighed, and duplicate samples are collected for 3 consecutive days. Water from each type of food is analyzed using a method such as direct drying, vacuum drying, infrared drying, distillation, spectrophotometry, and chromatography. This method can be applied to most foods, dishes, snacks, porridge, soup and so on. The advantages are high accuracy, reliable and suitable for most types of foods.[38] The disadvantage is that the method is complex and needs to be measured in the laboratory. Time, manpower and economic costs are high, which can't be carried out in large sample population.

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

Weighing method combined with food composition table: In this method, the actual food intake was weighed with electronic scales, and the water from each 100 grams of food was searched and recorded according to food composition table. Water intake from food (mL) = Weight of food intake (100 g) x water from food (mL/100g).[30,39] This method is generally suitable for calculating the water intake from fruit and packaged food with nutritional labels or milliliters of liquid. The advantages of this method are easy to be implemented with simple survey tools, which can be used in surveys with large scale of population. The disadvantage is that it can't be used to investigate the water intake from dishes after cooking.

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

According to the RDA of United States in 1989, water requirement was 1.5 mL per 1 kcal of energy consumption, which can be used to calculate adequate water intake.[1,8] However, the amount of sweat, physical activity, and other factors should also be considered when developing adequate water intake guidelines. The specific needs of young children, pregnant and lactating women, and the elderly should also not be neglected.

**Establishing recommendations on adequate water intake for the purpose of maintaining adequate hydration state**

Hydration state is determined by water intake and water loss. Dehydration refers to a deficiency of water intake, accompanying the disruption of metabolic processes, which is harmful to health.[30] The minimum water requirement is the amount that equals losses and prevents adverse effects of dehydration.[25] The establishment of adequate water intake should be enough to maintain adequate hydration. Studies showed that hydration state can be judged by urine, blood, tear and saliva osmolality, urine color, urinary specific gravity, body weight change, body fluid distribution, the amount of water intake and some other related signs. The common used criterions for judging dehydration state including the followings: 24-h urine osmolality > 500 mOsm/kg; morning urine osmolality > 700 mOsm/kg; blood osmolality > 290 mOsm/kg; tear osmolality > 309 mOsm/kg; urinary specific gravity > 1.020, and so on.[41-44] Body weight change is also commonly used as a judge index for acute hydration, and the degree of dehydration is positively correlated to the proportion of body weight change. Generally speaking, 2% body weight loss and more can be judged as dehydration state.[45] Studies have shown that the reduction of urine also meant that the body may be in dehydration state.[46] Normal urine color is slightly transparent yellow or white, however, urine color is gradually deepen when water intake is sufficient. According to urine color scale established by Professor Armstrong, some studies demonstrated that urine color scale >4 can be judged as dehydration state.[47,48] Relevant studies have shown that salivary osmolality increased from 54 mOsm/kg to 73 mOsm/kg when water intake was restricted for 48 hours.[49] In order to explore the relationship between urination frequency and hydration status, 87 adults were recruited and divided into groups of adequate hydration and dehydration state according to their urine specific gravity. The results showed that the 24-h urination frequency of participants in the adequate hydration state was more than that in the dehydration status (5±2 vs 3±1).[50] In a survey with 68 young adult men in China, it was showed that that 24-h urination frequency in dehydration state was significantly lower than that in adequate hydration state (7±2 vs 5±2).[30] In addition, the method of receiver operating characteristic (ROC) curve was adopted to determine the judge point of dehydration using the amount of water intake, and the results suggested that participants were in adequate hydration state when water intake was more than or equal to 2582 mL.[30]

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

Body weight, body surface area and other related factors are influence factors of water requirement. Studies have shown that adults should supplement 40 mL of water per kilogram of body weight.[51] For infants and young children, rate of water metabolism and body surface area are relatively large, thus, are more prone to be dehydrated. Therefore, when calculating water requirement according to body weight for infants, the amount should be adjusted and increased.[1]

**Establishing recommendations on adequate water intake for the purpose of disease prevention**

A new index, proposed intakes for preventing non-communicable chronic diseases (PI-NCD), is introduced in DRIs of Chinese Dietary Reference Intakes 2013 compiled by Chinese Nutrition Society.[1] The significance of proposing PI-NCD is to prevent non-communicable 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 NVD susceptible population reaches PI, the risk of NCD can be reduced. Dehydration reduced by insufficient water intake or excessive water loss, do harm to the health of body and increase the risk of cardiovascular and urinary diseases. Preventing or decreasing the risk of these diseases should be another important factor to be considered when establishing recommendations on adequate water intake. However, the related studies and the available information in studies on the associations between hydration and some specific diseases are far from conclusive. More studies on the relationship between water intake, hydration and diseases should be conducted to provide more evidences.

***Recommendations on adequate water intake in some countries and organizations***

Recommendations on adequate water intake have been developed by the World Health Organization (WHO), the United States, the European Food Safety Authority, and some other countries and organizations (Table 2).[1]

WHO: To avoid the dehydration state (24-h urine osmolality >500 mOsm/kg), WHO suggested that daily total water intake for sedentary men and women of 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 are advises to consume 3300 mL.[8] (Daily total water intake = adequate daily drinking water intake + adequate daily water intake from food).

European Food Safety Authority: In 2010, the European Food Safety Authority suggested that daily adequate drinking water intake for adults should be within the range from 1400 mL/d to 12 L/d depending on the temperature and physical activity. In further consideration of the data of water intake survey and the adequate urine osmolality to keep adequate hydration state, it 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 data about water intake in National Health and Nutrition Examination Survey III (NHANES III), it has been suggested that daily total water intake for men and women (aged 19 – 30 years) should be 3700 mL and 2700 mL, respectively, which are in accordance with suggestions in Canada.[8] In a joint proposal issued by Australia's National Health and Medical Research Council and New Zealand's Ministry of Health, it was suggested that daily total water intake should be 3400 mL for men and 2800 mL for women, and with daily adequate drinking water intake was 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 of 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 adult was 2500 mL and daily adequate drinking water intake was 1500 mL.[11] In Denmark, Finland, Norway, and Sweden in 2004, the recommended daily adequate drinking water intake for adults is 1500 mL, and it is suggested that lactating women should drink an extra 600–700 mL.[12] In United Kingdom, the UK Food Standards Agency and the British Dietetic Association recommended that the daily adequate drinking water intake be 1500–2500 mL under moderate climate conditions.[13]

### *Recommendations on adequate water intake in China*

#### Necessity of developing adequate water intake guidelines in China

Water requirements can vary considerably and are complex. It is inappropriate to develop an adequate water intake suitable for all countries. China is unique and it is necessary to develop specific adequate water intake due to specific dietary habits, heights, altitudes, and other environmental conditions.

Dietary habits: Water intake behaviors, such as beverage type, are different between China and Western countries. Water content in beverages varies: tea and coffee are 99.5% water, whereas skim milk, 2% fat milk, and whole milk are 91%, 89%, and 87% water, respectively.[1,25] In addition, Chinese residents' dietary compositions and cooking processes are also different from other countries. In China, the daily diet is mainly composed of plant-based foods with higher water content, and the cooking methods are mainly steaming, stewing, and stir-frying, all of which retain more original water content in foods than 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 the different dietary compositions in China, the contribution of metabolic water to total water intake is also different from that in other countries. Further, the dietary structures exist discrepancies in different regions of China, which will affect 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 to total water intake from food 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 vary significantly across its vast width: there are extensive alluvial plains in the east, high plateaus, and broad grasslands in the north; hills and low mountains in the south; China's two major rivers—the Yellow River and the Yangtze River—in the central-east; and a major mountain range in the west. In China, the climate is mainly dominated by dry seasons and wet monsoons, which lead to pronounced temperature differences between winter and summer. In the winter, northern winds coming from higher-latitude areas are cold and dry; in 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 other countries, which affect water requirements.

Height Difference: Due to genetic differences, the heights are different between Chinese and European or North American people. Height is directly proportional to body surface area, which may affect water requirements.[54]

## Principles, methods, and procedure of developing adequate water intake guidelines in China

Based on the data of water intake survey, adequate water intake were proposed in consideration of age, sex, physical activity, dietary habits, environment, energy consumption,

and kidney concentration capacity in China (Table 3).[1] However, there are quite specific challenges in formulating recommendations on water adequate intake.

Infants aged 0–6 months: Water accounts for a larger proportion of body weight. In addition, infants have a higher basal metabolic rate but immature kidney system, which makes them prone to water–electrolyte imbalance.[1] Thus, it is particularly important for infants to have optimal water intake. It is suggested that infants (aged 0–6 months) should only be fed with breast milk, with no extra water given. In China, the breast milk intake of infants (aged 0–6 months) is approximately 750 mL/d. Water accounts for 85% of breast milk. Therefore, the total water intake for infants (aged 0–6 months) is 700 mL/d.[1]

Infants (aged 7–12 months): The daily breast milk intake is approximately 600 mL. The amount of water obtained from complementary food and beverages is 330 mL/d. 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 provided by complementary food is approximately 550 kcal.1 It is calculated that, the water requirement for energy consumption is 825 mL (1.5 mL / per 1 kcal energy). Thus, the daily total water intake for toddlers (aged 1–2 years) is 1300 mL.[1]

Young children (aged 3 years): Due to 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 of 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. With their vigorous metabolism, their body temperatures rise more easily during physical activity. Therefore, young children should have sufficient water intake to meet their needs. Due to the lack of water intake data, the daily adequate drinking water intake for children aged 4–6 years was estimated using references of adults' data. 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 of children aged 4–6 years = Daily adequate drinking water intake of 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. (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; 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 carried out in four cities in China showed that the average daily drinking water intake was significantly higher in boys (1157 mL) than in girls (1026 mL). The average daily drinking water intake of boys aged 7–10, 11–13, and 14–17 years were 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; 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 in men (1679 mL) was more than that in women (1370 mL). The average daily total water intake for all participants was 3035 mL.[13] Based on these data, in consideration of energy consumption, physical activity, sweating, and solute load, the recommended daily total water intake for men was 3000 mL and for women was 2700 mL, with the daily adequate drinking water intake being 1700 and 1500 mL, respectively.[1]

The elderly: It was suggested that their daily total water intake be the same as that of adults. However, with an increase in age and the decline of kidney function and water balance recovery, older adults are more prone to be dehydrated and should cultivate a good habit of drinking water.[1]

Pregnant and lactating women: Pregnant women should drink an additional 300 mL of water to what non-pregnant women drink because of the need of the fetus and the formation of amniotic fluid. Lactating women should drink an extra 1100 mL of water because of the formation of breast milk.[1] In China, sufficient data is not available on water intake among pregnant and lactating women. With the reference of the data in other countries, the recommended daily total water intake for pregnant women was 3000 mL (daily adequate drinking water intake: 1700 mL) and 3800 mL for lactating women (daily adequate drinking water intake: 2100 mL).[1]

***Future prospects and applications***

In light of the limitations of available studies, future prospects and applications on related study should emphasize the following aspects.

At present, most of water intake only investigated the behavior of water intake, but hydration status was not evaluated based on related physiological indices. It is necessary to further objectively evaluate the hydration status by measuring the urine osmolality, specific gravity of urine, and other related physiological indices. In addition, only the recommendations on adequate water intake of children, adolescents and adults are developed based on the data of water intake among residents of corresponding age groups in China. The recommendations on adequate water intake among other age groups or physiological stages were proposed referring to the data of water intake among residents of corresponding age groups in other countries, or in consideration of the relationship between energy consumption and water requirement. Thus, first, further surveys are required 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 analyze the behaviors of water intake among older adults and pregnant and lactating women. More data on the water intake of people in different regions and during different seasons are also required.

Second, studies from abroad on the relationship between water intake, hydration state and health mainly focus on the aspects of cognitive ability, physical activity, urinary system and cardiovascular diseases. In China, there are few studies on the relationship between water intake, hydration state and health, such as the effects of hydration on cognitive ability. It is necessary to carry out more studies on relationship between water intake, hydration state and health, and further expand to different diseases, such as obesity, dyslipidemia, diabetes, metabolic syndrome, and so on. It would be helpful for estimating water intake requirements for preventing and decreasing the risk of related diseases.

Third, China is unique for many reasons and there are quite specific challenges in formulating such recommendations. There needs to be more studies on the differences in the methodology used to establish recommendations in comparison to the Chinese recommendations. The recommendation on adequate water intake must be further developed based on more scientific evidence and appropriate methods.

Fourth, it is imperative to transform the results of scientific research on water intake into health education. Health education related to water intake can help raise the awareness on the importance of water intake for the whole population, urge the whole population to drink enough water, to maintain a suitable hydration state, and eventually to promote health.

Finally, studies on the methods of water intake survey, water intake behaviors, and hydration and health is useful to inform and evaluate related public health programmes. National nutrition and health status are important indicators which reflecting the level of

social and economic development, health care and characteristics of population in a country. In 1959, China carried out a comprehensive nutrition survey, and gradually covered the survey on health status. Up to now, five large-scale surveys have been carried out and have been developed as one of national routine monitoring work in China.55 In previous surveys, dietary intake was the key point of the survey, while water intake behavior was only as additional information. Data on water intake was less and insufficient accuracy. With the deepening understanding on the importance of water, the deep-going of water intake studies, and the improvement of water survey methodology, it can be considered to incorporate more targeted water intake survey methods into this national routine monitoring work. This will contribute to a more comprehensive understanding on the characteristics of drinking water behavior among Chinese residents, to assess hydration status, to analyze the epidemic characteristics and change rule of related diseases, and then to formulate relevant policies and measures for disease prevention. Last, it will be helpful to promote the health of the whole people.

***Conclusion***

Taking adequate water intake helps to maintain optimal hydration and ultimately promote health. Recommendations on adequate water intake need to be developed to guide residents to have adequate water. Although some organizations or countries have developed recommendations on adequate water intake, the scope was somewhat limited. More surveys about water intake and more studies on hydration and health should be conducted among different groups of population to provide scientific data and evidence for further improvement and revision of the recommendations. It would be useful to inform and evaluate related public health programmes.

## AUTHOR DISCLOSURE

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

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**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 |

**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<br>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

**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